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COMPARISON OF THE CARBONIFEROUS AND PERMIAN FORMATIONS OF NEBRASKA AND KANSAS.

INTRODUCTION.

AFTER having devoted three summers to the study of the Upper Carboniferous and Permian formations of Kansas, the writer recently reviewed quite rapidly the similar formations of southeastern Nebraska, and in this paper will give an outline of their general correlation.

No particular formation was traced from Kansas into or across Nebraska, nor were the stratigraphic details worked out carefully in Nebraska; still the work done, limited as it was in character, showed the geologic age and general relation of the rocks of Kansas to those of Nebraska, and as various opinions are entertained regarding these relations it seems important to give a brief description of this work.

NEMAHA COUNTY.

Wabaunsee formation.—It is desirable to select the three counties—Nemaha, Otoe, and Cass—in which the greater part of the field work was done, for the general subdivisions of this paper and then under each county to describe its geologic formations, beginning with the oldest.

The exposures in the eastern part of Nemaha county along the Missouri River were very fully described by Meek,[1] sections

[1] Final Rep. U. S. Geol. Sur. Nebraska and adjacent Territories, Pt. II, Paleontology, pp. 109–114.

were given, together with lists of fossils from the vicinity of the towns, Peru, Brownville, and Aspinwall,[1] and the following species were reported by him from these localities:

1. *Neuropteris hirsuta* Lesqx.
2. *Neuropteris Loschii* Brgt.
3. *Fusulina cylindrica* Fischer.
4. *Productus nebrascensis* Owen.
5. *Productus semireticulatus* (Martin) de Kon.
6. *Derbya crassa* (M. & H.) Hall & Clarke.
7. *Meekella striato-costata* (Cox) White & St. John.
8. *Spirifer cameratus* Morton.
9. *Spirifer* (*Martinia*) *plano-convexus* Shum.
10. *Spiriferina kentuckensis* Shum.
11. *Athyris* (*Seminula*) *subtilita* (Hall) Newb.
12. *Nuculana bellistriata* (Stevens) Meek.
13. *Myalina perattenuata* M. & W.
14. *Aviculopecten Whitei* Meek.
15. *Edmondia aspinwallensis* Meek.
16. *Allorisma subcuneatum* M. & H.
17. *Bellerophon percarinatus* Con.
18. *Straparollus* (*Euomphalus*) *catilloides* (Con.) Keyes = *Euomphalus rugosus* Hall.
19. *Nautilus occidentalis* Swallow.
20. *Deltodus* (?) *angularis* N. & W.
21. *Productus longispinus* Sowb. = Nor. & Pratt.
22. *Chonetes granulifera* Owen.
23. *Bellerophon carbonarius* Cox.
24. *Bellerophon Montfortianus* Nor. & Pratt.
25. *Productus pertenuis* Meek.
26. *Productus cora* d'Orbigny.
27. *Myalina subquadrata* Shum.
28. *Aviculopecten occidentalis* (Shum) M. & W.

The fossils of the above list are nearly all well-known Carboniferous species as was stated by Meek.[2]

Marcou referred the rocks along the Missouri River in this county to the Dyas[3] (= Permian) but this view was thoroughly

[1] Fin. Rep. U. S. Geol. Sur. Nebraska, etc., pp. 109, 110, 112, and the "Tabular list, illustrating the geological and geographical range of the fossils of eastern Nebraska," pp. 124–127.

[2] *Ibid.*, p. 114.

[3] Bull. Soc. Géol. France, 2e série, t. XXI, 1864, p. 134.

disproved by Meek, who criticised Professor Marcou's correlation in the following words: "but upon what evidence he [Professor Marcou] does not say, nor is it apparent to anyone who regards fossils as any guide in identifying rocks, as those found here consist of the same forms constituting the group so often mentioned as characterizing the Coal Measures of the Western States."[1]

Meek regarded the exposures along the Missouri River in Nemaha county as geologically above the Nebraska City beds, for he said: "At Nebraska City, and below there, at Otoe City, Brownville, and Aspinwall, there are, perhaps, altogether, near 150 to 200 feet of additional strata, all holding probably a position above the geological horizon of the top of the boring at Nebraska City."[2] On the contrary, Dr. Hayden regarded the Aspinwall section as somewhat older than that at Nebraska City, for he said: "The rocks at Aspinwall are all geologically at a little lower horizon than the Nebraska City beds, and mostly beneath the Brownville beds."[3] In the Aspinwall section Meek reported a stratum of coal one foot ten inches in thickness, eighteen feet above low water of the Missouri River and another six-inch stratum eleven and one-half feet higher. No opportunity was afforded me to study this section, hence I am unable to state whether the coal lies at the base of the Wabaunsee formation or not; but all the rocks of this county exhibited along the bluffs of the Missouri River belong to that geologic series usually termed the Upper Coal Measures, for which Dr. Keyes has proposed the very appropriate name of Missourian.[4]

[1] Fin. Rep. U. S. Geol. Sur. Nebraska, etc., p. 114.

[2] *Ibid.*, p. 137; also see p. 123, where a similar statement occurs.

[3] *Ibid.*, p. 17.

[4] Am. Geol., Vol. XVIII, July 1896, p. 25; also see Iowa Geol. Surv., Vol. I, 1893, p. 85. The writer would suggest the following classification for the Upper Coal Measures of the Western Interior province:

Missourian series (Keyes), - - -	Cottonwood formation (Prosser)	
	Wabaunsee "	"
	———	———

The formations below the Wabaunsee have been recently studied by Drs. Keyes and Haworth, to whom the writer leaves the selection of names for the lower part of the series.

With the exception of the region adjacent to the Missouri River, the geology of Nemaha county was not described by Meek or Hayden.

About twelve miles northwest of Aspinwall and some 235 feet above Nemaha City, which is near the level of the Missouri River, and near the center of Nemaha county, is Auburn, the county seat. To a large extent, the rocks of this region are concealed by the thick deposit of loess, but there are occasional exposures along the streams or at favorable places on the bluffs or hills. In the vicinity of Auburn are a few outcrops of rocks which are referred to the upper part of the Wabaunsee formation. Along the highway, one and one-fourth miles directly west of Auburn, the rocks show for a short distance. The top of the outcrop is some thirty-five feet higher than the Auburn hotel, or approximately 270 feet above the Missouri River, and is just west of the Sheridan cemetery on the east side of the South Fork of the Nemaha River. The following beds occur in descending order:

	Feet
5. Rough yellowish limestone	1 = 65
4. Soft light gray to yellowish shales	2 = 64
3. Drab hard limestone that weathers to a light gray color. A few fossils — *Aviculopecten occidentalis* (Shum.) M. & W. and fragments of other species	2 = 62
2. Light gray and greenish shales, the lowest very white 1. Covered to the level of South Fork of the Nemaha River	60 = 60

These rocks are considered to belong in the upper part of the Wabaunsee formation; for on the upland two and one-half miles farther west and perhaps fifty feet higher is a ledge of light gray limestone composed to a considerable extent of specimens of *Fusulina cylindrica* Fischer which the author regards as the Cottonwood limestone of Kansas. There are a number of outcrops and quarries of this limestone on the upland in the western central part of Nemaha county, as well as a few exposures of the underlying rocks, but as they are only a few miles northwest of this eastern outcrop of the Cottonwood limestone they may be described in connection with it.

Cottonwood formation.—The most eastern outcrop of the Cottonwood limestone seen in Nemaha county is the one which is known as the Van Court or Keyes quarry and is three and three-fourth miles directly west of Auburn. Unfortunately my barometer at the time of my visit was not reading accurately; but its altitude is estimated as some 345 feet above the Missouri River. The Cottonwood limestone forms a massive light gray stratum four feet thick, moderately hard and filled with large numbers of *Fusulina*. When freshly broken the *Fusulinas* though slightly darker in color than the limestone are less prominent than on the weathered surface and are only conspicuous when seen through a magnifying glass. On the weathered surface of the rock the shells resist decay longer than the limestone and stand out prominently. One who has visited the large quarries of Cottonwood limestone in northern and central Kansas would be immediately impressed with this very striking similarity. Few, if any, fossils other than *Fusulina cylindrica* Fischer occur in this limestone: only an occasional fragment of a spine of *Archæocidaris* or a bit of shell was noticed. The section at the Keyes quarry is as follows:

	Ft. In.	Ft. In.
3. Shaly limestone containing *Athyris (Seminula) subtilita* (Hall) Newb. and a few other fossils - - - - - - -	1	=6 9
2. Light gray shales to shaly limestone - - - - -	1 9	=5 9
1. *Cottonwood limestone*, light gray massive *Fusulina* limestone	4	=4

The *Nemaha county quarry* which is the most extensively worked is the next well-exposed section of the Cottonwood limestone and is one and one-fourth miles west of the Keyes quarry. It is located by the side of the Burlington and Missouri River Railroad, five miles due west of Auburn and one mile north of Hickory Grove. The average of three barometric readings makes the bottom of the quarry 130 feet higher than Auburn or approximately 365 feet above the Missouri River. This is twenty feet higher than the base of the Keyes quarry which gives a dip directly east of twenty feet in one and one-fourth miles or at the rate of sixteen feet per mile. The follow-

ing section of the Nemaha county quarry gives a clear idea of the character of the Cottonwood limestone and associated rocks as they appear in Nebraska.

SECTION OF THE NEMAHA COUNTY QUARRY.

	Ft.	In.		Ft.	In.
5. Soil	3		=	12	10
4. Somewhat shaly light gray limestone used for riprap. Fossils common, especially *Athyris* (*Seminula*) *subtilita* (Hall) Newb.	2	10	=	9	10
3. Light gray shaly limestone changing to shales on weathered surface, used for railroad ballast. From 1 foot 1 inch to 1 foot 9 inches in thickness. Fossils not so common as in upper limestone	1	9	=		7
2. *Cottonwood limestone*, of light gray color, containing immense numbers of *Fusulina cylindrica* Fischer. In two layers, the upper 2 feet and the lower 1 foot thick,	3		=	5	3
1. Light gray to slightly yellowish limestone, which contains some almost white streaks and in places is bluish in color. Very few specimens of *Fusulina*. Bottom of the quarry	2	3	=	2	3

As stated above, No. 2 of the section contains immense numbers of *Fusulina cylindrica* Fischer with an occasional broken spine of *Archæocidaris* sp.; while in No. 1 there are very few specimens of *Fusulina*. This character agrees with the Cottonwood limestone at its typical localities in Kansas where the *Fusulinas* are only found abundantly in the upper part of the limestone. On this account it seems advisable to the writer to regard both Nos. 1 and 2 as representing the Cottonwood limestone of Kansas which will give it a thickness of five feet three inches in the Nemaha county quarry. The shaly limestones and shales above the Cottonwood limestone—Nos. 3 and and 4 of the section—contain a moderate number of fossils although none of the species are abundant. The following were collected:

Athyris (*Seminula*) *subtilita* (Hall) Newb.=*A. argentea* (Shep.) Keyes (c).[1]

Productus semireticulatus (Mart.) de Kon. (c).

[1] The relative abundance of the species is indicated in the following manner:

Derbya crassa (M. & H.) H. & C. (rr).
Pinna peracuta Shum. (?) only a fragment (rr).
Allorisma sp. fragment of an impression (rr).
Archæocidaris sp. fragment of spines (r).

Above the Cottonwood limestone in northern and central Kansas are about fourteen feet of yellowish, calcareous shales, the lower seven feet of which contain abundant fossils. In Nebraska no similar shales have been found above the Cottonwood shales. Perhaps the shaly limestones and shales—Nos. 3 and 4 of the above section—represent the Cottonwood shales, although the fossils are not nearly as abundant. If this supposition be correct, then they belong in the Cottonwood formation. Again it is possible that the Cottonwood shales are represented by the thin shale or shaly limestone, No. 3, which is between one and two feet in thickness; while No. 4 represents the shaly limestones at the base of the Neosho formation in Kansas.[1]

The *Gilbert quarry* region is six miles west and two and one-fourth miles north of Auburn or about two and one-half miles northwest of the Nemaha county quarry. Near the head of a small stream and by the highway are several quarries. One on the east side of the highway, just south of the Gilbert quarry, gives the following section:

	Feet	Feet
5. Coarse grayish shales to rather shaly gray limestone at the base	3	= 10¾
4. Massive gray limestone, fragments of fossils numerous (2 feet in Gilbert quarry)	1½	= 7¾
3. Rather coarse, grayish shales (shaly limestone in Gilbert quarry)	1¼	= 6¼
2. *Cottonwood* limestone, massive *Fusulina* limestone with small amount of flint and an occasional *crinoid* segment, and fragment of *Athyris*	3½	= 5
1. Grayish to slightly buff limestone without *Fusulinas*. Bottom of quarry	1½	= 1½

a = abundant; aa = very abundant; c = common; r = rare; rr = very rare, when but one or two specimens are found.

[1] See JOURNAL OF GEOLOGY, Vol. III, 1895, p. 766.

The Cottonwood limestone and the succeeding Nos. 3, 4 and 5 of this quarry are fairly well shown in Fig. 1.

The *Fusulina* limestone is filled with specimens of *Fusulina cylindrica* Fischer all the way through the massive stratum;

1. View of Cottonwood limestone just south of the Gilbert quarry, northwest of Auburn. The Cottonwood limestone is the heavy layer at the bottom. Then in ascending order are shown Nos. 2, 3 and 4 of the section.

but as in the Nemaha county quarry both Nos. 1 and 2 are regarded as representing the Cottonwood limestone of Kansas. The base of this quarry is forty feet higher than that of the Nemaha county quarry or approximately 405 feet above the Missouri River. Since it is two and one-half miles northwest of the Nemaha county quarry it gives between the two a dip of sixteen feet per mile to the southeast.

In a small run a quarter of a mile north of the Gilbert quarry and some seventy feet lower, the outcrop shows a ledge of light gray to buff rather hard limestone with shaly layers above and below. Fossils are few. *Aviculopecten occidentalis* (Shum.) M. & W. and *Cythere nebrascensis* Geinitz (?) occur in the shaly

layers and in some of them are large numbers of this minute Crustacean or a closely related species.

The *Carlisle quarry* is located on the northern edge of the rather steep bluff some distance south of the Nemaha River. It is nearly one mile north of the Gilbert quarry, and six miles west and 3 + miles north of Auburn. This is at the northern edge of the upland south of the Nemaha River and the farthest north that the Cottonwood limestone was found. In this quarry the base of the Cottonwood stone is about twenty feet higher than in the Gilbert quarry. The section of the G. W. Carlisle quarry is as follows:

	Feet	Feet
4. Shaly limestone	1½	= 7¼
3. Massive limestone	2	= 5¾
2. Shale	1¼	= 3¾
1. *Cottonwood* limestone. Bottom of quarry	2½	= 2½

Below the Cottonwood stone on the slope of the hill are thin ledges of smooth limestone alternating with shales. There is one stratum of limestone which on a weathered surface is rough and cellular something like the "dry bone" limestone in Kansas. There are also some reddish shales and the rocks, which for sixty feet below the Cottonwood limestone are partly exposed, resemble to some extent the upper rocks of the Wabaunsee formation in Kansas. These rocks are somewhat fossiliferous and in a bluish-gray shaly limestone from twenty to thirty feet below the Cottonwood limestone the following species were collected:

Aviculopecten occidentalis (Shum.) M. & W. (r).

Pleurophorus subcostatus M. & W. (?) Two rather large specimens which resemble the figures of this species quite closely (rr).

Allorisma (*Sedgwickia*) cf. *topekaensis* (Shum.) (Meek) (rr).

Edmondia sp. (rr).

Bellerophon sp. (rr).

In the region west of Auburn the highest rock found in place is the Cottonwood limestone with the shaly limestones immediately on top. The country to the west of the Nemaha county quarry rises from 100 to 125 feet higher, but a somewhat hasty search failed to reveal any ledges of rock in place, all being

quite deeply covered by drift and loess. On this high country seven and one-fourth miles west and one mile north of Auburn is a Burlington and Missouri River R. R. cut of ten feet which only shows the recent deposits, so that it would appear to be a difficult undertaking to find the bed rock on the uplands. This difficulty was experienced by Dr. Hayden who stated that: "From Tecumseh [the county seat of Johnson county, twenty-two miles west of Auburn] to the source of the Nemaha, about forty-five miles, I did not discover a single exposure of rock, and I could not ascertain that any had ever been observed by the settlers."[1]

From the facts stated above it seems reasonably certain that the massive limestone west of Auburn may be correlated with the Cottonwood limestone of Kansas. Lack of time prevented the actual tracing of this limestone south to the exposures of Cottonwood limestone in northern Kansas, yet its biologic and lithologic characters are so similar to those of the Kansas stone that it appears quite certain they belong to the same formation. In Kansas, the Cottonwood limestone is reported by Professor Knerr in the northeastern part of Marshall county where he states that it "disappears under the drift about five miles north of Beattie in Marshall county."[2] This locality is about fifty miles southwest of the Nemaha county quarry of Cottonwood limestone in Nebraska.

JOHNSON AND GAGE COUNTIES.

Wabaunsee formation.—Johnson county lies directly west of Nemaha county to the west of which is Gage county which extends south to the state line and is crossed by the Big Blue River. At Tecumseh in Johnson county about fifteen miles west of the Nemaha county quarry and from 100 to 200 feet lower, as far as I can judge from the data at hand, Dr. Hayden reported a

[1] Fin. Rep. U. S. Geol. Sur. Nebraska, p. 34.

[2] Univ. Geol. Sur. Kansas, Vol. I, 1896, p. 142. Also see "A Geologic Map of Kansas (preliminary)," Pl. XXXI, in the above work on which the line of outcrop of the Cottonwood limestone is represented.

stratum of coal from ten to fifteen inches in thickness.[1] In this connection it is interesting to state that Professor Knerr noted the occurrence of "a shale bearing a four-inch stratum of coal" which is given as from 50 to 100 feet below the Cottonwood limestone.[2] Again, in the vicinity of Tecumseh Dr. Hayden stated that "in a bed of limestone, holding a high position in the hills, the following fossils were found: *Spirifer cameratus, Athyris subtilita, Syntrilasma hemiplicata* [*Enteletes hemiplicatus*], *Productus semireticulatus*."[3] In Kansas, where the writer has carefully studied the stratigraphy and palæontology of the Upper Carboniferous and Permian rocks along the Kansas and Cottonwood valleys where they, as far as known, are more clearly exposed than at any other locality in the two states, *Spirifer cameratus* Morton has not been found above the top of the Wabaunsee formation, and from this fact the writer is inclined to refer the limestone mentioned by Dr. Hayden to the Wabaunsee formation.

Permian.—In Gage county, which lies next west of Johnson county, Dr. Hayden reported grayish and yellowish argillaceous limestones which he stated—"are undoubtedly of Permian or Permo-Carboniferous age, though they contain fossils common to both Permian and Carboniferous rocks."[4] He was not confident of the presence of Permian rocks in Nebraska for he said: "It is not certain that the true Permian beds, as recognized in Kansas, extend northward into Nebraska, though thin beds may occur in some of the southern counties."[5] And he further said that the Permian rocks "pass beneath the water level at Beatrice," the county seat of Gage county, and westward are the yellowish and dark brown Cretaceous sandstones, now known as the Dakota sandstone.

In 1886 Professor Hicks published a short paper about the rocks along the Blue River in Gage county which he designated provisionally as Permian and said that they were "distinguished

[1] Fin. Rep. U. S. Geol. Sur. Nebraska, p. 34.
[2] Univ. Geol. Sur. Kansas, p. 142.
[3] Fin. Rep. U. S. Geol. Sur. Nebraska, p. 34.
[4] *Ibid.*, p. 28.
[5] *Ibid.*, p. 28, footnote.

from the underlying Coal Measures by the absence of coal and black shales, and by the prevailing magnesian character of its limestones, by the presence of certain characteristic indurated marls and oölitic limestone, as well as by the new and distinct types of animal life."[1] These rocks are undoubtedly of Permian age and it is probable that the Neosho formation and possibly a part of the Chase occurs in Gage county. This supposition is supported by the statement of Professor Knerr that in Marshall county, Kansas, which adjoins Gage county on the south, there are about 250 feet of Permian above the Cottonwood limestone.[2]

OTOE COUNTY.

HISTORIC REVIEW OF THE GEOLOGY OF THE COUNTY.

To the north of Nemaha and Johnson counties is Otoe county which extends from the Missouri River on the east to Lancaster county on the west. This is an important county in the history of the geology of southeastern Nebraska because the cliffs near Nebraska City have been fully described by several geologists.

Owen in 1852 gave some account of the rocks along this part of the Missouri River, referring them to the Carboniferous. He briefly described the rocks in the bluff near Fort Kearney (the old name for Nebraska City) and reported *Productus costatus*, *P. Flemingii* = *P. cora*, and *Fusulina cylindrica*, which he says "previous to this discovery was only known in Ohio."[3]

Swallow in 1855 mentions strata at Fort Kearney and the mouth of the Little Nemaha which he referred to the "Upper Coal Series" of the Upper Carboniferous.[4]

In 1855 Marcou published a geological map of the United States on which the rocks along the Missouri River from the mouth of the Big Sioux to that of the Kansas River are colored

[1] Am. Naturalist, Vol. XX, p. 882.

[2] Univ. Geol. Sur. Kansas, Vol. I, p. 144.

[3] Rep. Geol. Sur. Wisconsin, Iowa and Minnesota, pp. 133, 134. See sections 34 and 35 M.

[4] 1st. and 2d. Ann. Rep. Geol. Sur. Missouri, p. 79.

as belonging to the "Terrain du nouveau Grès rouge" (Triassic system.)[1]

Marcou republished this map as a frontispiece of his *Geology of North America*, in which occurs the statement that "beds of *New Red Sandstone* . . . . cover and form the majority of the immense prairies bordering the rivers Missouri, Platte, Arkansas, and Red River of Louisiana."[2]

In 1857 Dr. Hayden published a geological map of Nebraska on which the rocks along the Missouri River valley from about fifty miles north of the mouth of the Platte River, south to the Kansas River in Kansas, are colored as belonging to the Carboniferous age.[3] The following year Dr. Hayden published a second edition of the above map on which the Carboniferous area remains about the same. To the west of the Carboniferous, the Permian system, which was not indicated on the earlier map, is mapped. This system is represented as beginning at a point a number of miles northwest of Nebraska City and then extending southward increasing in breadth to the southern part of Kansas. The base of the system is represented as crossing the Republican and Smoky Hill rivers several miles west of Ft. Riley, while its upper boundary crosses the Grand Saline and Smoky Hill rivers a number of miles west of the present city of Salina. In Kansas, small areas of Permian are represented on the high divides to the east of the main Permian area. Immediately west of the Permian or the Carboniferous where the Permian is absent, rocks are represented that are referred to the Lower Cretaceous.[4]

In 1863 Marcou and Capellini studied the Missouri River section along the eastern border of Nebraska and the following January Marcou published quite a full description of the rocks

[1] Carte Géologique des Etats-Unis et des Provinces Anglaises de l' Amerique du Nord. In Bull. Soc. Geol. France, Vol. XII.

[2] Op. cit., Zurich, 1858, p. 11.

[3] Proc. Acad. Nat. Sci., Philadelphia, Vol. IX, opposite p. 109 and on p. 110 the description of the area of the system.

[4] *Ibid.*, Vol. X, p. 139. For a statement of the distribution of the Permian, see p. 144.

in the vicinity of Nebraska City and referred them to the Upper Dyas or Permian.[1]

The following year Meek criticised the correlations of this paper, stating that "all the rocks seen by Mr. Marcou on the Missouri, from St. Joseph to the Cretaceous above Bellevere, belong to one unbroken series of Upper Coal Measures, as was first shown by Professor Swallow; with possibly the exception of some of the highest outcrops near Nebraska City, where there is a downward undulation, that may have left portions of the Permian on the high parts of the country."[2]

In 1866 Geinitz described the fossils collected by Marcou in Nebraska together with some from the Permian of Kansas,[3] and also concluded that the rocks in the vicinity of Nebraska City belonged to the Dyas.[4]

Meek in 1867, reviewing at length Professor Geinitz's work, failed to agree with him in many instances concerning the identity of Nebraska species with those of Europe;[5] he also reaffirmed his previous statement that the Nebraska City rocks with possibly the exception of the highest beds, belonged in the Upper Coal Measures.[6]

[1] Bull. Soc. Géol. France, 2e sér. Jan. 1864, Vol. XXI, pp.134–137. Marcou's conclusion, based on the fossils he collected being expressed as follows: "Les fossiles que j'ai trouvés dans cette section [Nebraska City] m'ont rappelé tout à fait le faune dyasique du Zechstein de la Saxe, et je regarde ces couches de Nebraska-City comme appartenant et représentant en Amérique la partie supérieure du dyas d'Europe," p. 137.

[2] Am. Jour. Sci., 2d ser., Vol. XXXIX., March 1865, p. 165.

[3] M. d. K. Leop.-Carol. Akad. d. Naturl.— Carbonformation und Dyas in Nebraska. Dresden, pp. vii+91. 5 plates.

[4] *Ibid.*, p. 89, where he says: "Die bei Nebraska-City vorkommenden Versteinerungen gehören einer Zone an, welche den untersten bis mittelren Schichten der deutschen Zechsteinformation (oberen Dyas) entspricht."

[5] Am. Jour. Sci., 2d ser., Vol. XLIV, Sept. 1867, pp. 170–188; Nov., pp. 327–340.

[6] Meek's statement was as follows: Those [rocks] by both of them [Marcou and Geinitz] referred to the Upper Dyas at Wyoming and Bennett's Mill and Nebraska City, with *possibly* the exception of divisions C and D [the higher beds] at the latter place, belong to the horizon of the Upper Coal Measures. The only point in regard to which there can be any reasonable doubt is, whether the divisions C and D at Nebraska City belong more properly to the horizon of the rocks Dr. Hayden and I termed Permo-Carboniferous in Kansas, or to the Coal Measures proper." (*Ibid.*, pp. 336–337.)

In 1868 Professor Marcou reaffirmed the Dyassic age of the Nebraska City rocks, stating that: "In Nebraska the Dyassic rocks form the right bank of the Missouri River from Aspinwall to Plattesmouth and Aureopolis, that is to say, all the bluffs of the counties of Nemaha, Otoe, and Cass. . . . . The best section of the Dyas of Nebraska and the most easy to be studied, is that formed by the bluff at the Nebraska City landing, at Otoe City, at Peru, and at Brownville, where the strata are higher in the Dyassic series than at Nebraska City; whilst at Rock Bluff, Plattesmouth, and Aureopolis, on the contrary, we find the lower layers forming the base of the Nebraska Dyas."[1] Following the above is a detailed section of the rocks at the Nebraska City landing accompanied by lists of fossils which were identified by Professor H. B. Geinitz. In 1892 Professor Marcou still regarded the Nebraska City rocks as of Lower Dyassic age.[2]

In the summer of 1867 Meek and Hayden spent about two months in carefully studying the rocks along the Missouri River from Omaha to Kansas. In 1872 an excellent work based upon this study was published in which Hayden discussed the general geology of southeastern Nebraska, and Meek gave a detailed account of the stratigraphy of the Missouri River region accompanied by a very careful description of the fossils.[3] This work has become a classic in palæontology for the Upper Carboniferous of the Mississippi Valley. The conclusion in reference to the age of these Missouri River beds agrees with the former opinion of Meek and is clearly expressed in the following sentences: "From all of the facts, therefore, now determined, it must, I think, be clearly evident that all of these strata under consideration along the Missouri, that have been by some referred in part to the Mountain limestone, in part to the Permian or Dyas, and in part to the Coal Measures, really belong entirely to the true Coal Measures; unless the division C, at

[1] Trans. Acad. Sci., St. Louis, Vol. II, p. 562.

[2] Am. Geol., Vol. X, pp. 369, 373.

[3] Final Rep. U. S. Geo. Sur. Nebraska and portions of the adjacent Territories, pp 245, 11 plates.

Nebraska City, and some apparently higher beds below there on the Missouri, may possibly belong to the horizon of an intermediate series between the Permian and Carboniferous, for which, in Kansas, Dr. Hayden and the writer proposed the name Permo-Carboniferous. . . . . It is true that in first announcing the existence of Permian rocks in Kansas, we also, upon the evidence of a few fossils from near Otoe and Nebraska cities, resembling Permian forms, referred these beds to the Permian; but on afterwards finding that these fossils are there directly associated with a great preponderance of unquestionable Carboniferous species; and that there is also in Kansas a considerable thickness of rocks between the Permian and Upper Coal Measures containing, along with comparatively few Permian types, numerous unmistakable Carboniferous forms, we abandoned the idea of including these Otoe and Nebraska City beds in the Permian. And all subsequent investigations have but served to convince us of the accuracy of the latter conclusion."[1]

It is to be noted in reference to this correlation of the Upper Palæozoic rocks of Nebraska with the Upper Coal Measures, that Meek did not intend to include the rocks in Kansas which he and Hayden had called Permian,[2] a fact which has been misapprehended by certain writers on the geology of this region. Since the report of Meek and Hayden, no contribution of importance has appeared relating to the geology of the Upper Palæozoic of Nebraska, consequently it is especially interesting to compare their conclusions with our present knowledge which has been enriched by the labors of the last quarter of a century.

CHARLES S. PROSSER.

[1] Fin. Rep. U. S. Geol. Sur. Nebraska, etc., pp. 130, 131.

[2] Trans. Albany Inst., Vol. IV, 1858, p. 76; Proc. Acad. Sci. Phil., Vol. XI, 1859, pp. 20, 21; and Am. Jour. Sci., 2d ser., Vol. XLIV, 1867, p. 37.

(To be continued.)

EVIDENCES OF RECENT ELEVATION OF THE SOUTHERN COAST OF BAFFIN LAND.[1]

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Introduction.—This paper is the outgrowth of the opportunity afforded for studying the lands at several places in and north of Hudson Strait, during the past summer, while a member of the Cornell Greenland party, with the sixth Peary expedition. Four stops were made in all along the coast of Baffin Land, three going up, as follows: Big Island; the mainland, just north of the island; and Icy Cove on Meta Incognita. The fourth landing was at Niantilik Harbor in Cumberland Sound on the return homeward.

[1] The writer is greatly indebted to various members of the expedition for valuable suggestions and help, especially Mr. Bonsteel, who stopped with him on the island; but, whatever value this paper may contain is largely due to Professor R. S. Tarr, who kindly directed the work throughout. To all the writer wishes to express his thanks and add his most grateful acknowledgments.

BIG ISLAND.

Location, description and topography.—The location of the island is immediately off the southern coast of Baffin Land, in Hudson Strait, and separated from the mainland by a narrow channel of water, ten to twenty miles wide, known as White Strait—in north latitude 62° 30′ to 63° and west longitude 70° to 71° 10′. It is some twenty-five to thirty miles in the direction of its longest axis, which is northwest and southeast, and has an average width of from five to ten miles. The coast is a steep and irregular one, being much cut up by fiords and embayments. The highest land reached on the island was 470[1] feet above sea level. Its surface has been deeply incised by interlocking fiordic[2] valleys, which are quite broad at their tops, with the ridges or divides between, of a typical moutonnéed form. These, of course, are on their tops narrow in proportion as the valleys are wide. The rise and fall of the tides is about thirty feet. The topography shows marked signs of glaciation, though, in places, it has been greatly modified by weathering, which has been chiefly of the mechanical kind and on a large and rapid scale. Notwithstanding the great amount of mechanical weathering, due almost entirely to frost action, chemical disintegration is distinctly noticeable. Many sections which have been but recently uncovered by ice are rough and angular, with nearly every trace of glaciated form obliterated.

Kind of rock.—The rocks consist of regularly banded hornblende-biotite gneiss, complexly folded and gray in color, the intensity of which varies according to the amounts of the dark minerals present. The gneisses are intersected by numerous pegmatite veins composed of the same minerals.

Proofs of elevation in raised beaches.—In nearly every valley studied, one of its most prominent and striking characteristics was the occurrence of shore lines in the form of distinct beaches. Sometimes a full and complete series of half dozen or more of these would be found in a single valley at different elevations,

[1] All altitudes were measured with an aneroid barometer.

[2] The term "*fiordic*" is here used in the sense of "fiord-like."

while in others only one or two would occur. These were, in most cases, well developed, level topped, and composed of well-rounded, water-worn material, four-fifths of which was distinctly

SKETCH MAP OF THE HUDSON BAY REGION.
BAFFIN LAND AND LABRADOR.

FIGURES REPRESENT THE LOCATION OF RAISED BEACHES WITH MEASURED ELEVATIONS ABOVE PRESENT SEA-LEVEL.
X. LOCALITIES IN WHICH RAISED BEACHES HAVE BEEN NOTED WITHOUT ELEVATIONS ABOVE SEA-LEVEL.

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derived from the local gneisses. However, they contained as well quite a noticeable quantity of foreign material, *e. g.*, shale, limestone, quartzite, etc. This material was variable in size in the lower beaches, and also in several of the higher, though noticeably uniform and coarse for the higher ones. With reference to the size of the materials composing these beaches, several different types

were represented, from the true sand and gravel, on the one hand, to the typical bowlder beach on the other, with all gradations between these two extremes. Except for the materials being covered with lichens, these are as fresh and perfect in every respect as though they had been formed but yesterday. In the majority of cases the beaches extended entirely across the valleys from side to side, although it was not uncommon to find them thinning out at one end, and only reaching from one-half to two-thirds the entire distance. They were variable in dimensions, in width from 10 to 50 yards, and in length from 60 to 110 yards. Their length depended upon the width of the valleys in which they were formed. In elevation they ranged from 270 feet above, down to sea level; and, so far as studied, could be correlated throughout.

The best developed and most uniform and regular series of beaches found were in a valley[1] which began at the north end of Ashe Inlet, with a direction[2] S. 13°.5 W. The divide in this valley is located nearer the southwest end, and about 1000 yards from its northern terminus in Ashe Inlet. Unlike most of the other divides on the island, which are composed of loose material, either glacial or beach deposits, this one is formed of the gneissic rock, in situ, and is exposed for the entire width of the valley with an elevation of 185 feet above sea level. The first beach is built immediately against this rocky divide at an elevation of 175 feet above sea, with an average width of some forty feet. The second beach is 165 yards beyond the first one, northward, at 125 feet above sea, and is the best developed one of the series in this valley, with a width of some one hundred feet. Between these two slight fragmentary ones are scat-

[1] It was on the south side of this valley, only a short distance from Ashe Inlet, that the Hudson Bay Company established their scientific station, or Observatory No. 3, in 1884; and it was in their house that we camped during our stay on the island.

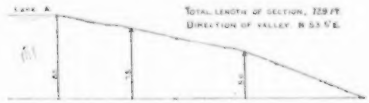
[2] Through the kindness of Mr. G. R. Putnam, of the U. S. Coast and Geodetic Survey, the writer has been enabled to give all bearings in terms of true North and South readings. Mr. Putnam states that the compass needle is rather unstable in these regions; also, there may be daily changes of several degrees, and the effect of local attraction is likely to be great.

BIG ISLAND

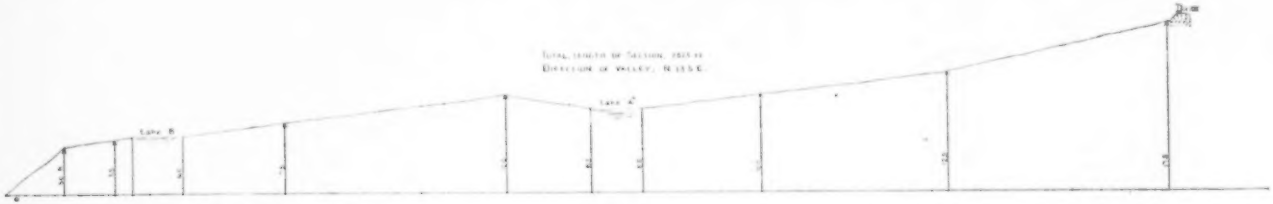
Profile from Sea Level to top of Uppermost Beach

1896

Profiles show the height of beaches above sea level.
Beach ridges shown by inverted Vs.
Height above sea level indicated in feet.



SECTION 2



SECTION 1

FIGURE 1

tered, within a few feet of each other. The third and fourth beaches are found at the same elevation, 100 feet, and about equally distant from the opposite sides of a rock-basin lake which has been formed in the intersection of this, with a second valley, whose direction is N. 53°.5 E. The fifth beach is found at an elevation of 75 feet, and at a distance of about 165 yards from the fourth one, with an average width of some 60 feet. This is the last well-developed beach in this valley, though there are two fragmentary ones found at the respective elevations of 55 and 50 feet above sea. These are located on the north side of and at a short distance from a second small lake, whose surface is 60 feet above sea and 75 yards from the fifth beach.

In the southwest half of the valley, which has been mentioned above as crossing the one just described, are found two well-developed beaches at the respective elevations of 50 and 75 feet, which are correlated with the two corresponding beaches in the above series.

In the next valley immediately beyond, eastward, and approximately parallel to the one trending S. 13°.5 W., is found the largest, and by far the best-developed, beach seen on the island. It is distinctly a sand and gravel beach, 40 feet high, with its crest 175 feet above sea, and about 120 feet wide by 330 long. It serves as the divide in its valley, and is the correlative of the 175-foot beach in the first series.

Proofs of elevation in differential weathering and unlike surface conditions.—The fact of recent elevation of this island does not rest alone upon the evidence of raised beaches, though this, to be sure, is entirely satisfactory in itself. It is confirmed by other geological evidence of a very strong nature. Apparently there exist on this island two sharp and well-defined zones, whose surface conditions, in nearly every respect, are very markedly different from each other. The first zone, which begins at present sea-level, and has its upper limit about 300 feet above sea, includes all the land below that level. This zone includes the hilltops for a distance of from two and one-half to three miles back from the sea, and the bottoms of all the major valleys observed on

the island. Excepting the valley bottoms, which are filled with quantities of unusually large and well-rounded bowlders, this belt has been stripped of its loose material in the form of glacial drift; consequently the bare and naked rock is exposed on the hilltops. The attack of the agencies of weathering upon the surface of this area has been in progress, more or less, ever since the rock was exposed, but the effect is far less than that over the areas above an elevation of 300 feet. This would naturally follow, since it will be shown that up to this elevation the waters have but recently subsided or fallen. By far the larger quantity of loose materials which are scattered here and there over this zonal surface is rounded and waterworn. Mechanical weathering has in places shown its effect, and angular masses are seen scattered about somewhat sparingly, in the form of small talus deposits. This zone will embrace at least three-fourths of the total land area of that part of the island visited.

The second zone has its lowest level and beginning at the 300-foot elevation and includes all the surface above, including an area which is not continuous, being merely the tops and sides of the hills for two-thirds of their distance downward. In this zone the bedrock is seldom seen, but is covered to an unknown depth with very large and loose angular blocks; in a few places, however, the bedrock outcrops at the surface in the shape of small knolls of somewhat decayed rocks. These angular rocks are clearly derived from the local gneisses, presumably largely, if not entirely, by frost action. In some cases they are weathered to a thoroughly crumbled condition. The scarcity of glacial bowlders in this angular mass was very striking, yet a few, which proved in each instance to be of foreign source were seen.

Along the sides, at an elevation of from 50–75 feet above the valley bottom, which was 220 feet above the sea, were noted patches of pebbles and bowlders, mostly the latter. These were deposited in small channel ways which had been carved by temporary streams flowing down the valley sides. Fully a half dozen of these were seen at different places on the same hill-

side and at the same elevation. A short distance above this the loose angular material commenced to cover the surface. These conditions would seem to indicate that the waters of the sea had their level near this elevation, when these deposits were formed in what then were the mouths of the present channel ways. Such loose and angular material as may have extended below that line was subjected to sea action. It was ground up and distributed in the usual way over the sea bottom. It might be of interest to mention that in this valley was found a series of beaches, four in number, which were distinct and perfect pebble beaches, deposited on a shelf rising some 50 feet above the valley floor.

For the sake of a brief comparison let us note the salient features of the two zones. The first zone is characterized by a seaward strip of land, some two and one-half to three miles wide, reaching an elevation of some 300 feet, with deeply incised valleys (a feature common to both areas) and occupied by raised beaches. This zone skirts the higher interior land area, which has been termed the second zone. Furthermore, this area has its rock bare and more or less polished by glacial action with but little material strewn over its surface, which, for the most part, is waterworn, with occasional talus slopes of angular rock. The second zone, which includes all the land above 300 feet, is covered deeply with large angular blocks, has its bedrock exposed in a few places only, and all glacial form mostly destroyed. The contact between these two areas is marked in places by pebble and bowlder patches along the hillsides in some of the valleys.

Palæontological evidence of elevation.—In one of the valleys, 270 feet above sea level, was found a large deposit of well-preserved shells, representing two genera living at present, *Macoma calcarea*, Chemnitz,[1] and *Mya truncata*, Linn. (?). These were not found in direct association with the beaches, but were only a short distance from one series, and were taken from a small area of black mud, not covered by vegetation.

Dawson refers to several cases in southern and eastern Can-

[1] The writer is indebted to MR. E. M. KINDLE for the identification of species.

ada where vertebrate remains, especially the whale, are associated with raised beaches. In speaking of the lower St. Lawrence in the neighborhood of Little Meta,[1] he says, "Bones of large whales occasionally occur on this terrace." After describing a beach on the island of Anticosti,[2] he says, "The bones of a whale were found on this beach." He further states that the same condition is observed along the shore of the St. Lawrence[3] and at Smith's Falls,[4] Ontario. The beach at the latter place has an elevation of 420 feet above the level of the sea.

Packard[5] refers to the same association on the lower Savage Islands. In each case invertebrate shells representing several genera and species were found occurring with the vertebrate remains, but in greater abundance, as would be expected.

Southern coast of Baffin Land, about twenty miles north of Ashe Inlet.[6]—Three stops were made on the mainland at different places, and at each one proofs of recent elevation were seen in the form of raised beach s. At the first landing, which was across White Strait to the north, and opposite the middle, of Big Island, about twenty miles from Ashe Inlet, the beaches were associated with other forms of evidence, above mentioned, as being present on the island; viz., fossils and difference in degree of weathering above certain heights. The rock of this part of Baffin Land is a fine-grained, garnetiferous gneiss, and thus differs from the rock of the island. The land is low near the coast, but rises into a series of hills which at a distance of a mile or more back from the sea reach an elevation of 700 feet, continuing to rise inland.

Raised beaches.—These did not attain so perfect a degree of development as those on the island. They were formed in very narrow valleys, crescentic in shape and concave seaward, damming back small ponds or lakelets. In one place, where this condition

[1] The Canadian Ice Age, 1894, p. 65.
[2] *Ibid.*, p. 159.
[3] *Ibid.*, p. 161.
[4] *Ibid.*, p. 203.
[5] Memoirs Bost. Soc. Nat. Hist., 1867, I, Part II, p. 226.
[6] The writer was landed on Big Island and did not visit this part of the mainland. For what follows he is indebted to PROFESSOR R. S. TARR, who has very kindly furnished him with all the facts.

was especially noticed, it looked in every way as though it were artificial; the crescentic beach, which held up a lake behind it, had been so regularly constructed that had it been in an inhabited region Professor Tarr states that he should have ascribed it to the hand of human beings instead of to nature's handiwork. These crescentic lines were composed of large bowlders, weighing from fifteen to twenty pounds, and in length were from 100 to 125 feet, rather narrow topped, probably six feet across, but several times this width at base. The exact counterpart of these was seen in process of formation in one place at sea level, in which the ice was an important factor in their construction. The ice, moving in strong tidal currents, bore along bowlders and ground them against the coast, forming a bowlder pavement of a very perfect kind.[1] Professor Tarr states that, due to the narrowness of the valleys, it would be impossible for these to form without the aid and action of the ice, for no waves could exist here which would transport and pile up such an accumulation of bowlders, particularly when below the zone of ice action the bottom is clayey.

Fossils.—The following genera of living shells were found: *Mya*, *Saxicava*, *Pecten*, *Terabratula*, *Balanus*, and several other living species. These were found in a blue mud, some patches of which were fifty to sixty feet across, in some cases covered with moss, and in others not. Fossils were also found at lower levels.

Weathering.[2]—Professor Gill independently suggested recent elevation purely on the basis of the weathering of the rock in place. In chipping and breaking off petrographical specimens he found a striking difference in degree and intensity of weathering, which he placed at an elevation of from 300 to 400 feet. The rocks below this elevation were found to be much less

[1] For action of similar kind described by PACKARD and FEILDEN along the Labrador coast see references in Bibliography.

[2] I am indebted to PROFESSOR A. C. GILL for kindly furnishing me with this fact. The exact elevation of contact marking the difference in degree of weathering was not determined.

affected or changed by the weathering agencies than those above this height.

Icy Cove, southern part of Meta Incognita.—Our second landing place was on the southwest coast of a peninsula lying between Frobisher Bay and Hudson Strait, and about sixty miles east of Big Island. This land is known as Meta Incognita, and the landing was at "Icy Cove," where the only Eskimo settlement in the Straits was found, called "Noogla."

The topography here was much the same as that of the other two places—very rugged—and like Big Island the coast was steep and rough, indented with embayments and rocky capes or headlands. The rock is a very coarse-grained granitic gneiss.

Raised beaches.—Two beaches were noted, composed of coarse, rounded material. No elevations were taken, but these looked to be about 50 and 100 feet, respectively, above sea level. A bench between the two beaches was seen, which appeared to be a wave-cut terrace, at an elevation of about 75 feet.

Niantilik Harbor, Cumberland Sound.—This was our last landing on the Baffin Land side. Niantilik Harbor is a fiord on the south side of Cumberland Sound. A stream of considerable size enters at this point, having its head waters in a series of true rock-basin lakes of rather large size.

Raised beaches.—It is along the west side of this valley that we have a series of unusually large and well-developed beaches. Unlike those described from the other localities, these are composed of fine material, excepting the topmost one, which consists of coarse shingle. The direction of the two principal beaches is approximately parallel to the stream, N. 75° 55′ W. The first one is at an elevation of 110 feet above low tide, 200 yards long, with an average width of 30 yards, and is composed of sand, gravel and pebbles.

The second beach is from 50–100 feet above the first one, fully three-quarters of a mile long and with an average width of 75 feet, and is built of very large bowlders. It is not so well preserved as the lower one, as it lies against a very high and steep scarp, with its flat-topped condition seen in only a few

places, and for rather short distances, the rest being almost entirely masked by the piling up of the products of weathering. An intermediate stage is represented by a beach some 50 yards long and as many wide, composed of very fine material, mostly sand and gravel, and acting as the divide in the very shallow valley in which it is built. The two large beaches grade or run into rock-basin lakes at their eastern ends.

The cemetery of Black Lead Island is built on a well-defined beach composed of sand and gravel, and is at an estimated elevation of between 100 and 125 feet above sea level. Beaches were noticed at several other places, but time would not admit of their study.

A condition, unlike that seen at any of the other places, was noticed on all of the lands enclosing this harbor, which, in itself, would have a tendency to indicate or suggest elevation. The condition was that of a form of rocky headland or cape of peculiar development, cut out of the solid rock, primarily, by wave-cutting and perhaps, subsequently, by ice erosion to an unknown extent. They were very numerous, extended seaward for quite a long distance, were very narrow—only a few yards at widest—and were of a remarkably level-topped condition, rising five to ten and twenty feet above sea level. At about the same level notches of wave-cut origin were more or less distinctly noticeable, and while time would not admit of their study, they apparently were in correlation with the capes. Partial evidence was found which seemed to indicate recent elevation of some 50–100 feet above the highest beach mentioned.

Evidence of present rising of the land on Big Island around Ashe Inlet region and at Niantilik Harbor.—At each of these places, in nearly every valley studied, was found a beach built of fine material, sand and gravel, at an elevation of from five to ten feet above high tide. The evidence of present upward movement at Niantilik is made stronger by the peculiar type of rocky headland, extending seaward.

Bell[1] has shown evidence of a like kind indicating a similar

[1] Canad. Geol. Survey, Rept. of Prog. 1882, 1883, 1884, pp. 26, 31, 33 and 35, DD.

uplift of the lands to the west of the region herein described, and with Tyrrell[1] has proven the raised or elevated condition along the west and southwest shore of Hudson Bay. Again, Bell[2] has produced sufficient evidence, although doubted by Tyrrell,[3] that the Hudson Bay region has been elevated in historic times; the elevation being believed to be in progress at present.

No landing was made on the lands along the south side of the straits, but during the summer of 1884 Dr. Robt. Bell of the Canadian Geological Survey was sent out as the geologist by the Canadian government, through the straits and into Hudson Bay, and he has described raised beaches on some of the islands to the west and southwest of Baffin Land. For convenience I quote from Dr. Bell's report:

Speaking of Cape Prince of Wales,[4] he says: "Beaches of shingle, as fresh looking as those on the present seashore, except that the stones are covered with lichens, may be seen at all levels, up to the tops of the highest hills in this vicinity. . . . . The materials of the raised beaches above referred to consist principally of gneiss with milk quartz from the veins of the neighborhood, together with a few fragments of yellowish gray dolomite, with obscure fossils, a hard and nearly black variety of siliceous clay slate, with an occasional bowlder of dark, hard crystalline diorite."

Concerning Digges Island,[5] he says: "Between this and the western extremity of the island the hills have a rounded outline, and raised beaches, composed mostly of coarse shingle, form a prominent feature on their slopes, all the way from high tide mark to their summits, the highest of which is between 300 and 400 feet."

Mansfield Island,[6] he says: "For many miles, the whole of the eastern slope of the island presents a succession of steps or

[1] Geological Magazine, Decade 4, Vol. I, 1894, p. 398.

[2] Am. Jour. Sci., Vol. I, Fourth Series, 1896, pp. 219–228.

[3] *Ibid*, Vol. II, Fourth Series, 1896, pp. 200–205. For other references to this region see Bibliography.

[4] Canad. Geol. Sur. Rept. Prog. 1882, 1883, 1884, p. 26, DD.

[5] *Ibid*, p. 31, DD.

[6] *Ibid*, p. 33, DD.

small terraces, mostly too low to be distinctly counted, but there might be a hundred of these between the sea level and the highest parts of the island visible. These appeared to be partly ancient beaches, and partly the outcropping edges of nearly horizontal strata."

Marble Island,[1] he says: "Even the bowlders and coarse shingle forming the raised beaches remain quite white, and these beaches appear as conspicuous horizontal lines against the dark vegetable matter."

Degree of rapidity of the uplift.— It is strikingly noticeable from the description of the beaches given above, as also from their study in the field at the various localities in which they occur, that the conditions suggest a difference in the rapidity of movement with which the land was raised above the waters at the successive stages and levels. The movement seems to have varied in intensity or rate for the same locality. In the case of the two highest beaches on Big Island and at Niantilik harbor, the conditions point very strongly indeed to a uniformly slow change in level. The interval between the two beaches at each of these places is marked by intermediate fragmentary lines. Materials are strewn thickly over the area between in an interlocking manner. This condition is strikingly absent from the land areas between the lower beaches. Thus the change in level from the second highest beach downward was sudden and rapid, and is better described as having taken place by *jumps*, so to speak; while above this line the change in level must have been less sudden and violent, and in character slow and gradual. At Icy Cove and the mainland to the north of Ashe Inlet, the conditions indicate the same sudden or rapid *jumping* movement as in the lower levels at Niantilik and Ashe Inlet.

Going still farther westward the lands along the west coast of Hudson Bay have been described as containing raised beaches, thus indicating recent elevation in that region. In speaking of the raised beaches in the Aberdeen Lake region, Mr. Tyrrell[2]

[1] Canad. Geol. Sur. Rept. Prog. 1882, 1883, 1884, p. 35 DD.

[2] Geol. Mag., 1894, Vol. I, decade 4, p. 398.

says that they are found at the following elevations above the lake, 290, 220, 180, 150, 105, 90 and 60 feet; also, "Similar raised beaches are found in favorable localities all along the shore of Hudson Bay." In Mr. Tyrrell's[1] account of his first expedition through the barren lands of northern Canada, he mentions raised beaches in two localities, one at Doobaunt Lake with an elevation of some 400 feet above sea level; the second at the mouth of Chesterfield Inlet and on the south side. In Tyrrell's[2] second trip through these regions raised beaches are mentioned near Ferguson Lake at an elevation of from 400 to 500 feet above sea level, and on the southwest side of Churchill River in the region of Deer River with an elevation of some 600 feet.

Conclusions.—1. The evidence favoring recent elevation of from certainly 270 to 300 feet above present sea level on the lands along the south and southeast coast of Baffin Land has been shown to be of the most conclusive character, and can be briefly summed up under three general headings.

a. In the form of raised beaches.

b. Unlike surface conditions intimately associated with a difference in degree of weathering at a well-defined elevation.

c. In the form of extinct life. The remains of several genera and species of living shells were found to be in greater or less degree directly associated with the beaches.

Furthermore, that the conditions attending this upward movement at least show that the rate of movement was not alike for all the localities studied, but rather indicates that for some the uplift was sudden and rapid, rising by jumps or strides, while for others it was more uniformly slow and gradual.

2. Conditions strongly favor a present movement on Big Island and in Cumberland Sound. This is shown in beaches found in a great number of the fiordic valleys, which are at present out of the reach of high tide by some five to ten feet, but so recently formed that not a sign of vegetation has commenced

[1] Geog. Jour. (London), 1894, July–Dec., Vol. IV, pp. 444–447.

[2] *Ibid.*, 1895, July–Dec., Vol. VI, pp. 445–447.

to grow on the beach materials. Also, by the peculiar type of rocky headland and wave-cut notches above described, and at about the same elevation as the lowest beaches.

3. It would further appear that the uplift along south Baffin Land was coextensive with that described by Bell and Tyrrell in the Hudson Bay region.

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ITHACA, N. Y.,
December 10, 1896.

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ITALIAN PETROLOGICAL SKETCHES.

III. THE BRACCIANO, CERVETERI AND TOLFA REGIONS.

Bibliography.—The modern papers dealing with these three regions petrographically are extremely few, and since some of them are not confined to the description of only one they will be noticed together here.

We begin, as usual, with vom Rath,[1] who devotes parts of one Italian "Fragment" to Bracciano and to Tolfa. The descriptions are largely topographical, though in the Tolfa paper the "trachyte" is described and an analysis given, and considerable space devoted to the alum mines of the district. With exception of the paper just cited and a few stray notices of rocks in Rosenbusch's "Massige Gesteine," practically all the other articles on the regions are by Italians. Of these the following are the only ones which need be named here.

Struever[2] published in 1885 an account of the ejected blocks and their minerals which are found to the east of Lake Bracciano, but does not touch upon the eruptive rocks proper. Many of the eruptive blocks, and enclosures of Lake Bracciano, are described by Lacroix.[3]

In the same year Tittoni[4] describes the so-called Agro Sabatino, which includes the trachytic hills immediately to the west of Lake Bracciano, the region southwest of it, and the masses of eruptive rock near Cerveteri.[5] He gives a good geological map on a scale of 1 : 50,000. The first half of the paper is

[1] Vom Rath, Zeit. d. d. geol. Ges. XVIII, 561–576, 585–607, 1867.

[2] Struever, Atti Acc. dei Lincei, Series 4, I, 1, 1885.

[3] Lacroix, Enclaves des Roches, Macon, 1893.

[4] Tittoni, Boll. Soc. Geol. Ital. IV, 1885, 337–376.

[5] He states that he was the first (in 1879) to discover the eruptive character of these hills.

devoted to the sedimentary terranes, while the latter half is taken up with brief megascopic descriptions of the eruptive rocks and their tuffs, and with their distribution. He considers that all of the eruptives are post-Pliocene.

The rocks of the Agro Sabatino collected by Tittoni, as well as others of the same region from other sources, were examined by Bucca[1] who also later[2] adds a note on the enclosures in the eruptive rock of Monte Calvario. His papers are entirely petrographical, and will be referred to later on in detail. Busatti[3] in the same year gives a description of a trachyte from Tolfa, to which Lotti adds some remarks on the genetic relationships. De Stefani,[4] later, also gives an account of the regions of Tolfa and Cerveteri.[5]

It will be evident from the above that the literature of the regions in question is of a very scanty description, the important leucitic rocks of Lake Bracciano being practically untouched, and the others not having been studied very fully. The regions in question are shown on the Tolfa and Bracciano sheets (Foglii 142 and 143) of the Italian Geological Map (scale 1 : 100,000).

THE BRACCIANO REGION.

Topography.—The center of this region is the large Lake of Bracciano. This is almost circular in shape and with a diameter each way of 9^{kms}. The surface of the lake is 164^{m} above sea level. On the north at Trevignano its symmetry is broken by a small bay which apparently represents a small explosive crater.

The depth of the water is not stated, though it seems to be much deeper than Lake Vico. There are no islands in the lake.

[1] BUCCA, Boll. Com. Geol. Ital., 1886, 212–223.

[2] BUCCA, Loc. cit., 377–379.

[3] BUSATTI, Proc. verb. Soc. Tosc. 4, Luglio, 1886.

[4] DE STEFANI, Boll. Soc. Geol. Ital. X, 487–499, 1891.

[5] In a paper received just before going to press, P. MODERNI (Boll. Com. Geol. Ital. 1896, Nos. 1 and 2), describes the Bracciano center. He regards the mass as the product of eruptions from about 50 centers surrounding the lake, and this not as a true crater-lake but as due to a sinking in of the surface. He does not touch on the petrography.

Surrounding it is a circle of hills, whose steep inner sides come down close to the water's edge, leaving only a narrow shore margin. These hills are highest on the north, where they reach their maximum elevation in Monte di Rocca Romana (602^{m}), and from this gradually diminish in height around the lake toward the southern shore, where their height at Monti is only 336^{m} above sea level. From this circular crest the land here, as at Bolsena and Vico, slopes gradually down on all sides at a low angle, and presents much the same characteristic features.

To the east of the lake are three maar-like craters described by vom Rath. The largest of these is the dry circular Valle di Baccano, about 3^{km} in diameter. Between this and Lake Bracciano lie Lake Martignano (whose water level is 43^{m} above that of Lake Bracciano), and the Stracciocappa Marsh. These are all surrounded by ridges of tuff.

The walls and sides of the Bracciano Volcano are built up of leucitic lava flows and tuff beds, except on the west. On this side we find two small non-leucitic centers. About 3^{km} due west of Bracciano is the group of low hills which include Monti Oliveto and San Vito. These are partially covered by leucitic tuffs, so that they are older than some of these eruptions. To the north of them is a small solfatara, whose floor is white through decomposition of the rocks, and where sulphurous vapors are abundantly given off. To the north of this again is Monte Calvario,[1] a domal mass of eruptive rock. According to Tittoni this rests on Pliocene beds.

Petrography.— In this region my stay was of very short duration, so that the specimens collected and the observations made were few. A study of the geological map and my own observations are, however, sufficient to show that we have to deal here, as in the other centers, with two prominent groups of rocks, a non-leucitic and a leucitic. The group of phonolites proper seems to be lacking, or perhaps is present in only small amount.

[1] It may be noted that BUCCA speaks of this last eruptive center as Monte Virginio. The hill of this name, which lies just north of Monte Calvario, is composed of tuffs enclosing blocks of leucitite, as shown on the geological map.

Toscanite.—The non-leucitic eruptive rocks of this region resemble the vulsinites and ciminites in containing basic plagioclase, as well as orthoclase, and are consequently quite rich in lime. They differ, however, in being much more acid, with SiO_2 from 63–72, and sometimes contain quartz. They, therefore, occupy a place intermediate between the rhyolites and the dacites. They correspond, in fact, very closely, both mineralogically and chemically, with the rocks of Monte Amiata described by J. F. Williams.[1] They also resemble the quartz-trachytes of Campiglia[2] and Roccastrada.[3] As these earlier known localities are in Tuscany (Ital. *Toscana*) this group of acid effusive rocks, characterized mineralogically by the presence of basic plagioclase, as well as orthoclase, with occasional quartz, and chemically by high silica and alkalies and (for the acidity) high lime, and low alumina, may be called *toscanite*. It may be mentioned that they also resemble certain rhyolites from Ponza and from the Euganean hills near Padua. They thus occupy the place in Brögger's[4] table filled by the group of quartz-trachyte-andesites, and in some cases are so acid as to fall in with his dellensite (dacite-liparite). They approach this especially in their low alumina. Analyses of typical toscanites will be found in Table I.

The rock of Monte Calvario is very much decomposed, so much so that good fresh specimens are difficult to find. I finally obtained some which are quite, though not entirely, fresh at a quarry on the southeast side where work was going on. The rock is rather coarse-grained and resembles many of the porphyries of our western states. The groundmass is light gray, and glassy feldspar phenocrysts abound, which are colored light yellow by the infiltration of ferruginous water. They are chiefly of sanidine with a smaller quantity of acid labradorite. Some

[1] WILLIAMS, Neu. Jahr. B. Bd. V, 381, 1885.

[2] VOM RATH, Zeit. d. d. geol. Ges. XVIII, 639, 1866. Also DALMER, Neu. Jahr. 1887, II, 206.

[3] MATTEUCCI, Boll. Com. Geol. Ital. 1890, 284 ff., and Boll. Soc. Geol. Ital. X, 670 ff., 1891.

[4] BRÖGGER, Eruptionsfolge bei Predazzo, Kristiania, 1895, 60.

quartz grains are present. Biotite flakes are not rare, though these and the augite phenocrysts have suffered much through weathering, being represented by brown limonitic spots in some of the specimens. Some large enclosures of a darker, fine-grained, vesicular rock were seen, which will be described presently.

In thin section the sanidine phenocrysts are seen to predominate over those of plagioclase. Examination of suitable sections of the latter shows it to be a labradorite of the approximate composition Ab_3An_4. They are clear, but inclusions are not uncommon, nearly always of brownish glass, and often in the shape of the host. A few instances of parallel growth were seen, a plagioclase core being surrounded by a border of alkali feldspar. This, however, forms one crystal individual with the plagioclase, and belongs to the same general period of crystallization, being sharply outlined and distinct from the groundmass. It is thus of a different character from the alkali feldspar mantles already noticed. A few rounded crystals of quartz are to be seen. The ferromagnesian minerals are represented by brown biotite and fewer pale green diopside crystals, both of which are much decomposed. The groundmass, which is almost holocrystalline, is made up chiefly of alkali feldspar flakes, very few laths being present, with some brown spots representing original pyroxene microlites. A little quartz may be present, but no plagioclase could be detected, though the rock is in such a condition that a satisfactory study of it was impossible.

This rock is described by Bucca as a quartz-trachyte. His description agrees closely with my own limited observations. He mentions, however, the presence of hypersthene, whose existence in my specimens may have been concealed by its well-known liability to decomposition.

The *enclosures* in this trachyte are apparently fragments of an early lava stream, brought up from probably no great distance below. They are dark gray, fine-grained and compact, and quite vesicular, though far from being scoriaceous. The line of junction between the enclosed and enclosing rock is sharp, and no

great amount of contact metamorphism is apparent. In the gray groundmass are large tabular glassy sanidines and some rounded grains of quartz, but no ferromagnesian phenocrysts are to be seen. In many of the vesicles are slender brownish black needles of breislakite, and hexagonal scales of tridymite.[1] These enclosures are much less decomposed than the trachyte surrounding them, though the sanidines are stained slightly yellow.

Under the microscope the structure is strikingly like that of a dolerite. Very numerous prisms of colorless diopside, slightly brownish on the edges, and long plagioclase laths, whose extinctions show them to be labradorite of the composition Ab_1An_2, with fewer orthoclase laths, lie in a holocrystalline mesostasis of orthoclase. Some comb-like skeleton forms of labradorite are also seen. Magnetite is present though not abundant. A few larger phenocrysts of violet augite are seen, and the few sections of the large tabular sanidine phenocrysts met with are clear and show only a few inclusions of glass and apatite. A narrow orthoclase mantle surrounds them. There were found a number of grains of the peculiar brown barkevikite-like hornblende noticed in a leucite-tephrite of Bolsena. The extinction angle of $\mathfrak{c}$ on c was 17° and the pleochroism was identical. No olivine is present, but apatite needles are quite abundant.

The vesicular structure of this rock shows that it is not a segregation proper, but an inclosure of an earlier solidified lava mass which had been erupted on the surface. The breislakite and tridymite were formed prior to the eruption of the toscanite, since they are present in cavities revealed by breaking open good sized masses of the enclosures. The rock corresponds mineralogically, and probably more or less closely chemically, with the vulsinites, though the structure is quite different. It probably represents one of the earliest outflows of the volcanic center, carried up by the later toscanite. Bucca (*op. cit.* 377) gives a very good description of these enclosures which agrees closely

[1] BUCCA also notes hypersthene and augite crystals.

with the above. The hypersthene he speaks of as present is perhaps to be referred to the barkevikite just mentioned.

The toscanite of Monte San Vito is structurally quite different from that of Monte Calvario. The predominating dark brownish black mass is highly vitreous, with a few irregular cavities which are lined with a light blue gray opal. Through this are scattered many quite large glassy tabular sanidines, in almost every case twinned according to the Carlsbad law. They are stained slightly yellow and many carry the bluish opal in the crevices. Some irregular quartz grains are also visible, but phenocrysts of ferro-magnesian minerals are wanting.

The large sanidines are seldom met with in thin sections, but of the smaller phenocrysts those of feldspar are the most abundant. Those of plagioclase are in the majority over those of orthoclase, and Michel-Levy's method shows this to be labradorite of the composition Ab_2An_3. The crystals, both of labradorite and of orthoclase, are automorphic and sharp in outline, showing the usual planes. They are clear and quite free from even incipient alteration. Inclusions of pale brown glass are common, often with a bubble and sometimes of the shape of the host. Pale diopside, apatite and magnetite are also included in the feldspars. These feldspars are often clustered together, but no distinct relative order of crystallization could be made out between the two. The diopside is in stout well-formed crystals, usually with a pyramid largely developed. It is almost or quite colorless, and inclusions are rare and almost wholly of brown glass. A number of small thick tables of brown biotite are present which invariably show a narrow border of fine-grained augite-magnetite aggregate. A few large grains of magnetite and some apatite needles complete the list. In my few specimens I could detect none of the hypersthene mentioned by Bucca as abundant. The groundmass is highly vitreous, consisting of a largely predominating light brown glass base, in which are sprinkled, with little evidence of flow structure, many minute orthoclase and fewer prismatic diopside microlites. Small magnetite grains are rare and are perhaps derived from

altered biotite, as may also be the case with part of the diopside microlites. An analysis of this rock by Dr. Röhrig is given in Table I, No. 1. It is seen to be as high in silica as a trachyte, low in alumina, with rather andesitic amounts of lime and magnesia, and in alkalies standing between the two groups, though the relative amounts of potash and soda are not what we might expect.

The rock just described, as well as similar ones from other localities in the region, are called by Tittoni "trachytic retinites." Bucca describes them as augite-andesites, with which name his descriptions agree very well, though it seems to me, as it does to de Stefani, that he unreasonably neglects the abundant sanidines and quartz. He speaks of hypersthene as abundant, and gives extinction angles for the plagioclase[1] from which he concludes that they must be very basic—"from labradorite to anorthite." According to him orthoclase only occurs as the large tabular phenocrysts, which is certainly not the case in my specimens.

Leucitite.—The leucitic rocks collected by me belong to three groups, leucitite, leucite-tephrite, and leucite-phonolite. Specimens of the first were obtained south of Lake Bracciano, from a flow at Crocicchie, from a similar, or the same, flow about one kilometer west of this and from the quarry at L'Uomo Morto southwest of the lake. A similar rock was seen also at Oriolo, northwest of the lake, but I have no specimen of it. They are all compact, dark gray, basaltic looking rocks, with some fresh well-shaped leucite phenocrysts (0.2 to 1 ^{cm}) and a few smaller ones of augite.

Under the microscope the phenocrysts present no remarkable features. The leucites are clear, somewhat cracked, show quite strong double refraction, and contain few inclusions. The augites are well shaped, pale green and not pleochroic, generally darker toward the center, and with an extinction angle of about 42°. Some are seen with a fringe of later dark green augite at the ends, which extinguishes at an angle of 50° and includes some magnetite grains.

[1] He says that they vary from 35° to 59°. There seems to be some error here.

The groundmass is almost holocrystalline, and is made up chiefly of small round leucites. In two cases these contain only few peripheral inclusions of augite and apatite needles, a peculiar feature being that around the leucite crystals proper as defined by these rings, is a late growth of leucite which extends irregularly and acts as a mesostasis for the other constituents. In rock from the second locality mentioned the inclusions are more numerous, and in spots due to skeleton growth, as has been previously described, though the skeleton forms are not as perfect as some of those seen elsewhere.

Between these leucites is an interstitial mass of green or greenish brown augite needles and grains, with some magnetite grains, with the latter being associated flakes of orange red hematite. Spots of a colorless feebly doubly refracting substance, giving bright grays of the first order in my very thin sections, are referred to alkali feldspar, as treatment with acid revealed no nepheline. No melilite was seen. Glass base is present in a very small amount. An analysis of one of these leucitites is given in Table I, No. 5.

The leucitite of Santa Maria di Galera,[1] which belongs to this volcano, resembles the above very closely under the microscope, though it is much coarser in structure. A rock very similar to these is found as loose blocks in the yellow tuff of Monte Virginio. This is very much finer grained than any of the preceding; contains some plagioclase but no glass.

Leucite-tephrite.—This seems to be quite common in the region though not so much so as leucitite. It is represented by a specimen from a lava stream in the crater wall just below the town of Bracciano. It is rather dark and fine grained, but rough in texture and not aphanitic. Scattered through the groundmass are very many small clear leucites and some very small black augites.

Under the microscope it closely resembles the similar rock of the Bolsena region, having the same doleritic structure. The irregularly shaped leucites show strong double refraction, and

[1] ROSENBUSCH, Mikr. Phys. II, p. 1233, 1896.

carry few inclusions. The augite is in stout prismatic crystals, green in color and generally darker toward the center. Large grains of magnetite abound, which are accompanied by orange hematite flakes. Many lath-shaped crystals of a basic labradorite, with a little orthoclase, are present with these, and the interstitial colorless glass base contains only few augite microlites and some minute opaque grains. An analysis is given in Table I, No. 6.

Leucite-phonolite.— My only specimen of this was collected at a rather thick flow on the northwest shore of the lake close to the water's edge. The groundmass is compact and fine-grained, of a very light gray color and with a slightly greasy luster. Clear rather glassy leucites and minute black augites occur as phenocrysts. Examined with the microscope the large leucites show the twinned structure very finely, and the prismatic augites are of an olive-green color, with the pleochroism and other characters of aegirine-augite.

In the holocrystalline groundmass are many small olive-green aegirine-augite prisms, a few colorless haüynes showing the characteristic inclusions, and some magnetite grains. The feldspars are represented by stout crystals and grains of alkaline feldspar, which are occasionally twinned. There is also present a residual base of colorless, feebly doubly refracting nepheline, whose identity was established by treatment with acid and fuchsine. Plagioclase is absent. A peculiar feature of the groundmass is the presence of round spots of a clear substance, whose outlines are defined by rings of minute augite microlites with some magnetite grains. These seem at first sight to be groundmass leucites. Close examination under crossed nicols, however, reveals the fact that only a small percentage of them is really of this mineral. The majority are composed of nepheline, with some orthoclase grains and crystals, the latter occasionally in fan-shaped aggregates. We have here, then, a case of paramorphism of leucite into "pseudo-leucite"—a mixture of nepheline and orthoclase, such as has been observed in Arkansas,[1]

[1] J. F. Williams, Ark. Geol. Sur., 1890, II, 267.

Brazil,[1] and Montana.[2] It is difficult to understand why the small groundmass leucites should suffer this change, while the larger phenocrysts remain preëminently fresh and unaltered.

Bucca does not describe any of the leucite rocks of the Bracciano region.

THE CERVETERI REGION.

This region[3] lies about 10^{km} southwest of Lake Bracciano and north of the small town of Cerveteri, so famous for its Etruscan tombs. It consists of a small group of hills, extending about 8^{km} W. N. W. and E. S. E. (about parallel with the coast line, and 4 to 5^{km} broad. They are of no very great altitude, the hills reaching their maximum height of 384 meters in Monte Cerchiara, in the center of the group. I could only spend the better part of one day at the eastern end, but as far as my observations permitted me to judge they are a mass of domal eruptions resting, as Tittoni points out, on Pliocene beds.

They are composed almost exclusively of acid non-leucitic rocks and their tuffs. Some leucitite is met with at the eastern end, but these leucitic lava streams probably belong to the Bracciano volcano proper. Since this leucitite is met with beneath the "trachytic" masses, its occurrence is of great interest as showing that the earliest leucitic outflows of Bracciano are of an earlier date than those of Cerveteri, though they continued after these latter had ceased. There seems to me to be an intimate connection between the Bracciano center and that of Cerveteri, and probably also that of Tolfa, but my opportunities for observation were so few that I do not feel able to discuss this point at present.

Toscanite.—To this group belong all the specimens collected by myself, and also apparently all those described by Bucca, except those of a few leucitites. Their prominent mineralogical and chemical characteristics have already been noted.

[1] HUSSAK, Neu. Jahrb. 1892, II, 146.

[2] PIRSSON, Am. Jour. Sci., II, 194, 1896.

[3] It is included on the Bracciano Sheet (Foglio 143) of the Italian Geologic Map.

The rock of which Monte Cucco, at the extreme east end of the region, is composed, is a light gray porphyritic rock, many glassy feldspar phenocrysts and some of biotite lying in a rather vitreous brownish groundmass. Under the microscope there appear well shaped and uncorroded clear orthoclase and plagioclase phenocrysts, the former in the majority. The plagioclase is shown by Michel-Levy's method to be labradorite of the composition Ab_2 An_3, the symmetrical extinction angles of the lamellæ of the Carlsbad individuals being in one individual 26° and in the other 29°. There are also many tables of an olive green biotite, which shows no corrosion or alteration phenomena. A few large colorless diopsides also appear. There is no magnetite, and no quartz could be detected.

The groundmass is highly vitreous, the glass base being colorless or of a very pale brown. It shows perlitic cracking in great perfection. Through it are sprinkled small (0.01–0.02) microlites of diopside, and a few stout orthoclase microlites which often show "horns" at each end. An interesting feature is the occurrence in abundance of very small (about 0.05^{mm}) forked and sheaf forms of orthoclase, which correspond to the so-called keraunoids in Ischian trachytes already described by the writer.[1] These keraunoids are of such minute dimensions that they exert only a feeble action upon polarized light, but examination of the largest shows that the axis of greatest elasticity **a** lies parallel to the length, and that therefore they are elongated in the direction of the axis *a*. The use of high powers proves that they are in every way identical with those described from Ischia, except that they are of much smaller dimensions and more delicate.

Bucca's description of this rock closely agrees with the above, though he speaks of the biotite as being brown, and the small augites and keraunoids seem to have been lacking in the groundmass of his specimens. Though no quartz is present he is of the opinion that these rocks are to be referred to the same acid group as those of Monte Calvario. This opinion is con-

[1] WASHINGTON, Am. Jour. Sci., I, 375, 1896.

firmed by my analysis given in Table I, No. 2, which may be taken as representative of the rocks of this region.

The rocks of Monte Lungo and Monte Ercole, west of Monte Cucco, are rather darker and rougher in groundmass, and look like the Arsotrachyte of Ischia, minus olivine. The plagioclase is, however, rather more basic, having a composition Ab_1An_2, and the biotite rather browner in tone though still green, and colorless diopside phenocrysts rather more frequent. The glass base is rather dark brown, and the small orthoclase keraunoids are much more abundant, as are also the diopside microlites, which are here prismatic in habit. The rock of Belvedere del Principe south of Monte Ercole, is also closely similar in general characters, but the orthoclase keraunoids are here so abundant as to give the base a hyalopilitic structure. The glass is brown and the diopside microlites are prismatic in habit and show some flow structure.

It may be noted that absolutely no magnetite is to be found in any of these rocks. Small apatite needles are found in all, especially as inclusions in the feldspars. Bucca mentions a brown hornblende as present, known by its prismatic angle and oblique extinction, but careful research failed to reveal it in my specimens. As has been said, analysis No. 2 of the Monte Cucco rock may be regarded as representative of them all, and its close resemblance to that of the Tolfa and Calvario rocks will be noted. Further remarks on these points must be reserved for the final paper.

Leucitite.—This is represented by a specimen from a flow met with at the bottom of the deep ravine immediately to the west of Monte Cucco, whose rocks overlie it, though tuffs and soil conceal the contact. It is almost identical with the leucitites from the south of Lake Bracciano, and is composed essentially of round and irregular leucites with insterstitial green augite needles. Some magnetite and a very little orthoclase are also present.

The rock of which the ruined Castle Dannato is built was obtained from some now forgotten quarry in the neighborhood.

It is also a leucitite, and of the same composition as the preceding. It is, however, of much finer structure and closely resembles the leucitite of Sassi Lanciati near Bolsena. It carries segregations of coarse-grained, granitic masses, made up of large grains of green augite and a few well formed crystals of olivine, with much leucite which shows excellent twinning lamellæ, and which takes the place of the feldspar in typical gabbros. Some cavities are filled with calcite. These segregations closely resemble the leucitic blocks briefly described by Lacroix from Lake Bracciano, and may be compared with the Missourite recently described by Pirsson.[1]

THE TOLFA REGION.

This region consists of a triangular group of hills, lying a little more than 10^{km} northeast of Civita Vecchia and some 20^{km} west of Lake Bracciano. Its highest point is Monte Sassicari, 525^{m} above sea level. Since my visit of a few hours was confined to the southern angle I will not go into the topography, which moreover presents little of interest here. It may only be noted that the hills are composed essentially of toscanite, which in general is so extremely decomposed to alunite that a fresh specimen of rock is indeed a *rara avis*. De Stefani points out that the eruptions in all probability took place in post-Pliocene time, differing in this from Ponzi and others, who would place them earlier.

Petrography.—According to vom Rath there are two distinct kinds of "trachyte" represented in the region. The one is a "sanidine-oligoclase-trachyte" with light gray compact groundmass, in which lie phenocrysts of sanidine, oligoclase and biotite. This is more abundant in the northeastern part of the region, often shows a bed-like parting, and is comparatively little subject to decomposition. The other is more like a pitchstone, and is almost universally decomposed. Its groundmass is dark brown and resinous, with phenocrysts of sanidine, biotite and

[1] PIRSSON, Am. Jour. Sci., II, 315, 1896.

augite. To these Busatti adds a third variety, though his description hardly seems to warrant the separation.

I am inclined to agree with de Stefani in thinking that there is only one kind of rock, and that the differences noted are of very small importance. From vom Rath's analysis of the pitchstone-like trachyte and from mine of the rock from Tolfa it will be seen that the two varieties closely resemble each other chemically and that the rock belongs to the group of Toscanites as already defined.

The only fresh specimens which I obtained were collected at the hill on which stands the old castle above the village of Tolfa. In all other places I found it so decomposed as to be absolutely worthless for petrographical study. The groundmass is very compact and bluish gray, and speckled with minute black spots of augite. Very many large glassy feldspar phenocrysts, which often show twinning, with some biotites are scattered through it.

Under the microscope this rock presents an appearance almost identical with that of the Monte Cucco rock. The rather abundant plagioclase is an acid labradorite having the composition $Ab_1\ An_1$, as determined by the extinction angles (22° and 23°) of the albite-twinned lamellæ of the two individuals of a Carlsbad twin.[1] The feldspar phenocrysts are quite often corroded. The hyalopilitic groundmass has a colorless glass base, which is thickly crowded with diopside prisms and laths, rather than keraunoids of orthoclase.

De Stefani[2] mentions a leucitic rock which he obtained at the base of Monte Elceto between the toscanite and the underlying Cretaceous rocks. Rosenbusch, to whom a specimen was sent for examination, reports that it is a "leucitite perfectly identical with the leucitic rocks of Albano and the vicinity of Rome."

[1] BUSATTI states that the plagiolase is oligoclase, but his determination seems to rest on insufficient data, as he only mentions its "polysynthetic structure" but gives no angles, as neither does VOM RATH.

[2] DE STEFANI, Boll. Com. Geol. Ital., 1888, 224.

TABLE I.

	1	2	3	4	5	6	7
SiO_2	64.04	66.24	65.19	67.61	47.89	49.73	55.87
Al_2O_3	14.48	15.64	16.04	14.04	18.25	19.20	21.82
Fe_2O_3	1.73	1.16	1.16	....	4.93	5.50	2.34
FeO	4.35	2.19	2.48	5.40	3.64	2.41	1.10
MgO	1.03	0.89	0.99	0.65	3.68	2.63[1]	0.48
CaO	4.00	2.17	2.92	3.71	8.70	7.96	3.07
Na_2O	4.14	2.05	2.26	5.50	2.60	1.99	4.81
K_2O	3.65	6.60	6.11	2.41	8.23	9.39	10.49
H_2O	2.06	3.25	1.85	2.28	0.65	1.19	0.34
TiO_2	0.28	....	....	....	0.77	....	....
	99.76	100.19	99.00	101.60	99.34	100.00	100.32
Sp. Gr.	2.542	2.455	2.509	2.537	2.781	2.655	2.551

1. Toscanite, Monte Calvario, Bracciano, A. Röhrig anal.
2. Toscanite, Monte Cucco, Cerveteri, H. S. Washington anal.
3. Toscanite, Castle Hill, Tolfa, H. S. Washington anal.
4. Toscanite, Tolfa, vom Rath, *op. cit.*, 596.
5. Leucitite, Crocicchie, Bracciano, H. S. Washington anal.
6. Leucite-tephrite, Bracciano, H. S. Washington anal.
7. Leucite-phonolite, Lake Bracciano, H. S. Washington anal.

HENRY S. WASHINGTON.

[1] By difference, through loss of Mg precipitate.

MODE OF FORMATION OF TILL AS ILLUSTRATED BY THE KANSAN DRIFT OF NORTHERN ILLINOIS.

PERHAPS at no time during the Quaternary era were the climatal conditions of Illinois of such a nature as to originate a glacier independently of the ice introduced into the territory by outflow from the vast *névé* to the northeast. Consequently, when near the culmination of the Kansan epoch, a very early representative of the Lake Michigan glacier overspread nearly the whole of the territory of the present state of Illinois, it advanced across a region in which the indurated rock was but thinly covered by a nearly continuous mantle of residuary material, mostly clay, sand and angular gravel; and the ice thereupon proceeded to manufacture this into till. In a part of northwestern Illinois, especially in Stephenson county, the glaciation was of short duration and never repeated, and this district therefore, presents one of the best fields for the study of the contact phenomena between the base of the glacier and the preglacial land surface. There are scattered over the area incomplete deposits representing every stage in the process from solid rock to typical till. By a careful study of these imperfectly formed masses of till we may infer the process by which the ice manufactured the residuary material and underlying rock into the various types of deposits due directly to glacial action. The necessarily limited nature of this paper will compel me to state the hypothesis which seems to best explain the phenomena known to me, and simply refer to the localities where each stage is illustrated, mentioning a few of their most significant features.

The ice, in advancing across Stephenson county, moved westwardly, and within fifteen miles of the Driftless Area, in a decidedly northwesterly direction. During this time of general

advance, glacial abrasion was at a minimum, and had the ice then melted from this district, without further movement, its drift phenomena would be insignificant and uninteresting. But it so happened that, during the general recession of the glacial front, there were repeated slight readvances, forming a peculiar variety of incipient moraine, consisting of knolls and short ridges of angular limestone débris and of stratified water-worn gravel and sand. Between the marginal accumulations of a distinctly morainic type, there are other deposits of somewhat similar nature, but which belong to the so-called ground moraine. In other words, the period of most pronounced glacial action in the Kansan epoch in northern Illinois, occupied a position considerably later than the culmination of the epoch. This I attribute to a milder climate, causing a recession of the ice-front, but yet giving more free movement to the glacier and softer material to work upon. I have gone into this short explanation of the glacial history of Stephenson county, so as to exactly locate the age of the deposits the significance of which I propose to discuss.

We may gain some idea of the condition of the surface previous to the arrival of the ice by a study of a north-south belt along the eastern boundary of Stephenson county, and about thirty miles back from the glacial boundary. Here we will find frequent exposures of the semi-decayed upper portion of the Galena limestone with its overlying undisturbed residuary clay.[1] The Galena formation is usually a heavy-bedded, sub-crystalline dolomite, shaly in certain thin layers and extensively jointed and fissured. Within ten to fifteen feet of the surface, weathering has opened certain deposition-planes, separating the rock into layers from two to four inches in thickness. As the rock is composed of small rhomboidal crystals, the next stage of decay consists of a solution of the bond between the crystals resulting in a loose mass of angular grains, macroscopically

[1] This is finely displayed in a road cutting one mile south of Egan in Ogle county, and in an excavation of the Chicago and Great Western railway, two miles east of German Valley in Stephenson county.

resembling fine yellow sand. By a continuance of the process the crystals are dissolved, leaving a slight residue which, accumulating to a thickness of two to ten feet, becomes a highly oxidized, dark red, very fine-grained, structureless clay. Certain layers of the dolomite abound in chert, which breaks up into angular fragments, averaging about the size of a walnut. These abound in the residuary clay, and on hillsides often pass horizontally from the solid rock into the red clay, with but little disturbance of the lines of stratification. This is one of the strongest proofs of the undisturbed nature of the residuary clay at the localities previously mentioned. In fissures and pit-shaped holes in the surface of the rock, the red clay may extend down from ten to thirty feet. This particular form of its occurrence can be observed in almost any rock-cutting in the county.[1]

1. The first effect of the contact between the base of the glacier and the mantle of residuary clay, was a rearrangment of the latter. It was pushed forward and downward, but as its downward progress was limited to a slight compression, the effect was a crushing or kneading of the mass. The faint evidence of stratification in the undisturbed deposit furnished by the layers of chert, was totally destroyed and the fragmental chert scattered indiscriminately through the mass. All deposits of rearranged residuary clay are referred to this stage when they contain no foreign material whatever. As they, in many cases can be proven to have been moved but a very short distance, their transportation and deposition were clearly exclusively subglacial.[2]

[1] For a thorough discussion of the residuary material accumulating over the Galena limestone in unglaciated areas, the reader is referred to CHAMBERLIN and SALISBURY'S excellent report on the superficial geology of the Wisconsin Driftless Area in the Sixth Annual Report of the U. S. Geological Survey.

[2] A careful study of the county of Stephenson would probably afford several hundred localities — of very limited extent, however — where the process of till making was stopped in this first stage. Good exposures can be found by following the C. G. W. R. R. from South Freeport to Egan, or the I. C. R. R. from Feeeport to Everts. Another, exposed in a small ravine on the south side of Yellow creek, is important from the fact that the rearranged residuary cherty clay has been pushed off of its original rock ridge onto the surface of a lake deposit.

2. The process in the second stage is merely a continuation of the last. The material has been transported farther, kneaded longer and more thoroughly commingled. In addition, a small percentage of foreign drift, mostly well-rounded pebbles of small size, has been worked into the deposit. Still, at the completion of this stage, the fine-grained, dark red clay basis and predominance of angular white chert indicate the close relation between this very incomplete till and the undisturbed residuary material. This is the nature of the ground moraine over practically the entire northern half of the county. But in looking for exposures of it, it is necessary to remember that the upper three feet of the typical or completed till in this district have been highly oxidized during the following interglacial epoch, so that in color they often resemble the deposits of stage No. 2. The latter never were of any other color than dark red and reddish brown.[1]

The mode of transportation of this imperfectly formed till appears to have been exclusively subglacial. In a very large proportion of exposures in Stephenson county, there is a continuous section from an undisturbed preglacial residuary clay, through every gradation to what may be considered typical of the "semi-residuary" class of drift. There is absolutely not an iota of evidence that any of this material has been lifted from the earth's surface and enclosed in ice. Clear evidences of a kneading or rolling over of the mass are abundant.

3. There existed under the glacier, certain areas where deposition was being carried on at the same time that abrasion was active in others. So that, while in many portions of the county, the manufacture of till was carried into the second stage only, on certain closely adjoining areas this was but the beginning or early stage of the glacial action. In these latter, the ice after having removed the red clay, proceeded to attack the loose sand-like mass of dolomite crystals, which it quickly disposed of by incorporating with the deposits of stage No. 2, furnishing their first

[1] This red till is best exposed in several cuttings of the I. C. R. R., about three miles southeast of Winslow, in Stephenson county.

supply of calcareous material. A few sections show it interstratified with till, and it can sometimes be traced back to its original undisturbed position.[1] Having been transported but a score or at most a few hundreds of feet, there is no room for anything but subglacial action.

We have disposed for the present of all the loose material on the surface of the solid rock, and we now come to the most interesting part of the process.

4. Stephenson county is a comparatively hilly region, although the hills are not high, steep, or close together. A section through a hill would show the Galena limestone as a series of practically horizontal layers, not cemented, but held in position by gravity and the projections on the upper and under surfaces of the layers. The ice in moving westwardly across the country, upon ascending the eastern slope of a hill from which the loose material had been removed, exerted a powerful pressure on the edges of these layers. Near the top of the hill, the pressure overcame the friction, and the upper layers of the rock were pushed forward, sliding on a lower unmoving stratum. In many cases, these transported rock ledges were not broken up, but moved forward as a solid mass, being found in that condition to day. They may be ten or fifteen feet in thickness, and several hundred feet in length, and perfectly horizontal, so that the fact of their not being *in situ* would not be known were it not for their unusual position, partially obstructing valleys, producing a topography radically different from the preglacial; and from their overlying drift of various kinds, including stratified water-worn gravel; and more often than otherwise underlain by loose angular gravel from ten to thirty feet in thickness.[2] In transportation they were clearly pushed in front of or under the extreme marginal portions of the ice. None of them have been removed far from their original position, and this with much

[1] Small exposures of it, after being disturbed but before being combined with the red clay, may be seen at nearly every outcrop of the latter, notably in the railway cuttings of the southeastern part of the county.

[2] Locality where best exposed — six miles east southeast, of Freeport, in a high ridge, on the north side of the I. C. R. R.

other evidence, negatives the idea that the basal portion of the glacier "plucked" these huge masses of rock from the ridges and transported them in its body.

Sometimes the pressure of the ice resulted only in a slight folding, or a tilting and faulting of the rock strata without moving them to a distance from their original position. This may affect them to a depth of twenty or thirty feet, and may include some of the solid, heavy-bedded, unweathered layers. In these cases, at least, no question can remain that the action was extra-glacial or marginally subglacial. Their importance lies chiefly in the fact that they prove beyond dispute that even the Kansan ice-sheet could, at times, exert powerful forward pressure on the rock over which it moved.

5. The forward movement of the unbroken rock mass was rarely continued many scores of yards before some obstruction was encountered, often in the form of an upward slope of the land, increasing the friction to such a degree that the transported ledge was unable to withstand the pressure and general fracture resulted.[1] In a few cases, the impression made on the observer is that the mass remained unbroken while the stress accumulated, until, becoming too great, the entire ledge was suddenly fractured into innumerable small angular pieces, under a well-known principle recognized as a condition of the formation of certain limestone breccias in various portions of the earth. Usually, however, there is clear evidence of a kneading or rolling over and crushing of the mass, producing an internal structure which cannot be simulated by the product of any other known process. When a series of semi-decayed or loosely compacted strata being forced forward in front of the ice, are checked by some obstruction, they tend to corrugate in a manner somewhat similar to the Appalachian type of mountain building; and the disturbance is greatest in the vicinity of the obstruction. But when the ice

[1] The deposits representing this stage are quite numerous in the Pecatonica basin, over an area about three miles in diameter, lying immediately southwest of the village of Dakota, and another west of the village of Everts. They are usually in the form of dome-shaped knolls and short ridges, and forming conspicuous features of the drift topography, it is unnecessary to more minutely describe their localities.

overrides the deposit, if the basal friction is great enough, it will turn up the strata in contact with it, twist them over on to the as yet undisturbed strata, and inaugurate a motion in the mass which may be not inaptly compared to the movement of a roller under a heavy weight. Rarely, however, will the actual action be as perfect as it should theoretically be, but usually there is combined with the rolling process a forward and downward thrust which crushes the mass. The more resistant portions of the ledge break into huge angular blocks, the semi-decayed layers into smaller fragments intermingled with a great quantity of calcareous sand. The rolling is obviously produced by the "drag" of the forwardly moving glacier, while the thrust is the result of its great weight. This kneading process is not only theoretically probable, but has given rise, as I have already intimated, to phenomena in Stephenson county, Illinois, which are explainable only under the supposition of having been produced by its action.

6. By a continuance of the kneading process, the larger blocks are crushed, all evidences of the original lines of stratification are destroyed, and the deposit for the first time bears a slight resemblance to certain very stony tills. Few of the particles are smaller than the crystals of which the original limestone was composed, and, therefore, the deposit may still be classed with the "transported rock ledges." Moreover, in this stage there are practically no foreign rock fragments although a few Canadian pebbles may be found imbedded in it far from the surface, proving its glacial age.[1]

7. The process of manufacture between the last stage and the typical glacial till may proceed along several lines, all similar in the general features of the method, but differing in details. Several deposits along the Galena road, one mile northwest of Freeport, and along the C. G. W. R. R. between German Valley and Egan, seem to represent a stage slightly in advance of that just described. Here the angular limestone débris is com-

[1] A deposit representing this stage is finely exposed in a gravel pit, one mile north of Freeport, where the angular gravel overlies water-worn drift gravel.

mingled with a considerable quantity of rounded drift of which a large portion consists of Canadian bowlders. The foreign material may reach as high as 50 per cent. of the mass, but usually falls below 10 per cent. The bowlders belong to the "englacial" drift, and the deposits containing them are marginal, but I introduce them here because by a marked readvance of the glacial front, they may be reworked into till.

8. In other cases, the ice was transporting the red, imperfectly formed till, described under stage No. 2, contemporaneously with the angular limestone débris, and they often came in contact, either becoming thoroughly commingled or perhaps only interstratified. When the intermingling is complete, the deposit has the appearance of a very stony till of a light brown color, and the material of which is evidently mainly of local derivation.[1]

9. Just previous to the incursion of ice into the Pecatonica basin, in Stephenson county, its area was occupied, at the lower levels, by several successive extra-glacial lakes, which deposited glacial silts, some of which resemble typical loess, and others a modified or water deposited till. During the glaciation of the region, the abrasion of these comparatively soft silts was remarkably small, yet sufficient to leave an impress on the character of the till which now overlies them. For it is observed that, while the ground moraine over the northern half of the county, where these silts were poorly developed and rarely reached by the ice, is very similar in color and texture to the residuary clays, over the southern third of the county, where the land lies lower and the extra-glacial silts were strongly developed, the ground moraine is in general of a quite different character. The marginal deposits are similar in both districts (consisting largely of angular limestone débris and stratified water-worn gravel and sand), but on the inter-incipient-morainic tracts in the southern district, there is often seen a till identical in all important respects with that which is exposed in long and repeatedly glaciated regions

[1] Typically developed along the road between Egan and Lightsville in Ogle county, about two miles north of the latter village.

and which I have referred to as "typical till." It is a stiff, unstratified, light yellowish gray clay, containing irregularly disseminated subangular blocks, largely of local derivation, but also an appreciable percentage of foreign rock fragments, many of which are Canadian in origin. The Niagara limestone pebbles are next in abundance to the Galena limestone and chert, and are often beautifully striated. A belt of this variety of glacial clay occupies the country between Yellow creek and a high upland area about four miles south of it. Its eastward and westward limits are indefinite, but its length may properly be included within ten miles. It can be observed best by proceeding due south from Freeport, where at the distance of about four miles, it will be seen to assume distinct drumloid characters. In particular, one of these *pseudo* drumlins, while it has a core of stratified sand and gravel, is overlain by an eight-foot stratum of yellow till so nearly identical in constitution with the typical till of a highly glaciated region, that no appreciable difference could be detected. This drumlin (?) is also the best locality in this county for securing finely striated stones. Now, a careful study of the composition of this till belt shows that, (*a*) the mass of its clay may be referred to abrasion of the silt formations which it frequently overlies; (*b*) its foreign rock fragments must have been brought into the district by the ice-sheet, but independently of the accumulation of the till, their occurrence in which is an accident of deposition; (*c*) the iron in the till was derived from the residuary clay of the region, as was also the large amount of angular and subangular white chert; and (*d*) the subangular Galena limestone blocks which are quite abundant but generally overlooked because of the more attractive appearance of the foreign drift, must have been derived from the country rock, very close to its present position, by the process which has been described in this paper.

It may be objected to the first proposition that the difference between the till in this limited belt and that in the remainder of the county, may be due to a greatly increased introduction of foreign material along some line as the broad, shallow basin

which occupies the southern third of the county. The existence of this basin I recognize as the cause of the much larger proportion of foreign drift pebbles in its vicinity, for it favored subglacial transportation of them, but I do not think it alone can explain the phenomena connected with the above described belt of typical till. For (1) when we go east on the line of glacial movement, the characteristics of this till disappear, and in the extreme eastern portion of the county, what little till we do find in the Pecatonic basin, is mostly of the very imperfectly formed "semi-residuary" variety; and (2) if we study the limits of this characteristic till belt and the direction of ice movement, in connection with the limits of the main body of the extra-glacial lake clays and silts, we find such a relation between them as to clearly indicate the derivation of a large portion of the former from the latter.

In short, the composition of the till in the belt now under discussion, points to its being only a stage in advance of that described under stage No. 8, this advance being due chiefly to the introduction of a large amount of clay and silt, the result of an accidental passage of the ice over a semi-plastic lake deposit, which resisted erosion comparatively well, but yet suffered some abrasion at its surface. Therefore, as the yellow till occurs over and in the immediate vicinity of the stratified clays, there is no room for an englacial transportation, which is, moreover, quite unnecessary, and in opposition to the comparative abundance of striated pebbles.

In summarizing the evidence presented in the preceding pages, I would subdivide the product of direct glacial action, in the central Pecatonica basin, into classes as follows:

Class I. Semi-residuary drift. Till composed largely of rearranged red residuary clay and chert, with comparatively few foreign pebbles.

Class II. Angular local limestone débris. Varies between contorted, tilted, and transported unfractured rock ledges, and fine limestone breccia.

Class III. Consisting largely of a combination of the two

preceding with the addition generally of Canadian pebbles and small bowlders. Usually seen in marginal deposits.

Class IV. Typical till. Light yellow gray calcareous clay containing pebbles and small bowlders of local and foreign derivation, many of the latter beautifully striated.

The divisional lines between these classes, in the Pecatonica basin, must always be arbitrarily placed, as there are gradations from those deposits which are typical of one class to those which are typical of another. There is, also, no definite rule in their distribution for, while the four classes evidently represent four successive general stages in the process of manufacturing typical till, and should, therefore, naturally be expected to occupy successive belts from the outer glacial boundary back or east, they are in reality scattered indiscriminately over the entire district. However, Class I prevails in the northern half of the county; Class II in a north and south belt which, extending across the county, has its western boundary on a meridianal line which passes a few miles west of Freeport, and dies away to the east near the Winnebago county line; Class III prevails over a belt several miles in width extending diagonally from the southeastern corner of the county to near Freeport; and Class IV is principally developed south of Yellow creek, over and near to the remnants of the Lake Pecatonica clays.

Perhaps the most remarkable feature of the drift of this county is its anomalous distribution. Over the western one-third of the county, the drift, although comparatively thin, is generally distributed. Over the central belt, the evidence of vigorous glacial action is strongest. While in the extreme eastern one-fourth of the county, which was glaciated longest, there is very little drift of any kind, and there are areas, several square miles in extent, of nearly bare rock, and others where the preglacial residuary clay still remains undisturbed. It is evident that the conditions which controlled glacial action varied locally within wide limits, so that excessive abrasion of the rock surface might occur with a less weight of ice and a less length of glaciation, than on a neighboring area with similar

topography would not suffice even to remove the residuary clay. When I make the statement that the four classes of glacial deposits discriminated in this district, occupy hills equally as high, as narrow, and as steep, also occupy valleys equally as

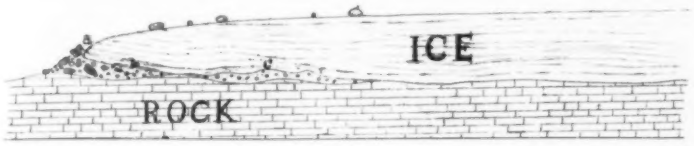

FIG. 1.— The Kansan ice at work in northwestern Illinois.

deep and broad, and trending in the same direction, we are prepared to accept the following conclusions :

1. That certain glaciers, notably that which glaciated northwestern Illinois, in passing over a slightly hilly region, exerted very unequal pressure on the land surface, *this inequality not always being directly due to the topography of the immediate vicinity.*

2. In crossing hills of moderate height, they sometimes strongly abraded the crests, while on closely adjoining areas they deposited ground moraine on hills of similar height and shape.

3. The areas of maximum and of minimum glacial action were generally permanent, or approximately so, throughout the time of glaciation.

4. In studying areas in the Kansan drift region or at least that portion of it which is in northwestern Illinois, the relative length of the glaciation in different localities cannot be even inferred from the apparent severity of the glacial action.

In conclusion, I will state in more definite language what I conceive to have been the position with relation to the mass of the ice, of the unstratified drift of Stephenson county, Illinois. The derivation, transportation, and deposition of the material occurred mainly under the peripheral portion of the glacier. Here, through the thinning of the edge, the weight was less, and the force of the ice movement having decreased, there was a

tendency of the extreme marginal portion to turn up, producing a base of a form somewhat as in the accompanying figure.

There was a struggle for the mastery between the advancing ice and the accumulating débris. The incipient morainic or marginal deposits of Stephenson county, including the transported rock ledges, belong to the extreme outer border of the ice and were transported least. Those which are most thoroughly kneaded belong to a position at about *b*. The drumlin (?) area south of Freeport may be placed at *c*, while much of the ground moraine was formed and deposited still farther back under the ice. By recession and repeated slight readvances of the ice-front, with a partial reworking of old deposits, the apparently indiscriminate distribution of the drift of this county may be accounted for. When the ice melted away entirely, the englacial bowlders which had become superglacial through ablation of the border portions of the glacier, and are so represented in the figure, came to rest upon the surface of all the other drift of the district and the areas of nearly bare rock represented at *a*.

If the advance was continued far, the ice overrode the coarse angular gravel at *a*, crushed it finer, brought up "semi-residuary" till and a little foreign drift from farther back, and combined them into typical till. This gradually fell behind the advancing border of the ice, and was redeposited as ground moraine, locally accumulating into drumlins and smoothly undulating drift areas, while the extreme outer portion of the glacier was forming a new deposit of angular local limestone débris.

OSCAR H. HERSHEY.

FREEPORT, ILL.,
January 5, 1897.

THE GEOLOGY OF THE SAN FRANCISCO PENINSULA.

THE Coast Ranges of California embrace an extensive region in which are presented complicated but exceedingly interesting geologic problems. Much attention has been given to these mountains for many years, but with the exception of a study of the quicksilver deposits, it is only recently that we have had presented in a thorough manner the results of the detailed examination of local areas.

Professor Lawson's recent report upon the geology of the San Francisco Peninsula[1] is perhaps the best yet made of any local area in the Coast Ranges and illustrates well what modern methods of research can accomplish in a complicated field. Notwithstanding the excellencies of the report, there is an infelicity displayed in the discussion of several problems which is regrettable in a study of this kind. This has, however, necessarily resulted from the method pursued, in that the investigator has given his attention almost exclusively to a narrow field of complex geology and has failed to make use of the results of the work of others, concerning questions which the phenomena in that field did not illuminate. It is absolutely necessary for the appreciation of many facts in any local area, and for the philosophic discussion of the history of that area, that the student should have a general knowledge of the relations existing over the region as a whole.

As a result of some experience in the Coast Ranges I feel called upon in the interest of geological progress to express most profound objections to a number of conclusions reached by Professor Lawson concerning some of the vital questions involved in the geological history of this region. Consequently in answer to his frank request for friendly criticism, I will take up the dif-

[1] U. S. Geol. Sur., 15th Annual Report, pp. 405-476.

ferent points which I feel are open to question in the general order in which they occur in the report. There are several statements in a synopsis of this report,[1] published a year and a half ago, which will be included in the criticism. There is a failure, which is without doubt due to an oversight, to give recognition to some contemporaneous and earlier work in the same general field and upon the same topics.[2]

Passing over the Montara granite and the associated marbles which exhibit the same relations and have without doubt the same history as similar rocks in the Gavilan and Santa Lucia ranges, we come to the author's Franciscan series, the oldest uncrystalline terrane. Professor Lawson divides it into five petrographic divisions. The lowest consists of conglomerate, sandstone, shale, etc., and is well exposed at Point San Pedro. He considers that this division may possibly be older and underlie the strata north of San Pedro valley unconformably, because fragments of shale similar to that at the point occur in the sandstone north of the valley. The fact seems not to have been noticed that fragments of similar shale are found in the basal conglomerate on the point. The conglomerates are identical in character with those at the base of the Golden Gate series on the Monterey coast, and are without much doubt of the same age.

The "foraminiferal limestone" and "radiolarian chert" form perhaps the most interesting portions of the series. They are dwelt upon in detail, particularly the "cherts." According to Professor Lawson the latter are hard siliceous rocks of varying degrees of purity, and are "prevailingly of a dull brownish red color, although other shades occur." He says that "in many

[1] Am. Geol., June 1895.

[2] Bull. Geol. Soc. of Am., Vol. XI, pp. 71–102. The results of this work were read before the Geological Society of America nearly a year in advance, and published six months prior to the first of the papers under discussion. The subjects concerned were the position and character of the marbles of the Coast Ranges, and especially the rocks constituting the Golden Gate series (Franciscan series of Professor Lawson), the nature of the sandstones and the radiolarian origin of the jaspers, as well as the geologic position of the series.

cases they are true jaspers and have been so designated in some of the earlier descriptions of them." After discussing their variability he again says: "In view of this variation in petrographic character, it has been deemed best to refer to these rocks by the old and familiar name of 'chert.'" It seems to me that, on the contrary, the designation "chert" is not only not as appropriate for rocks of this character but it does away with "an old and familiar name" for no sufficient reason. The designation "jasper" was used by Blake, Newberry, and Whitney. According to Geikie, "Chert is a name applied to impure calcareous varieties of flint in layers and nodules which are found among the Palæozoic and later formations, especially but not exclusively in limestones."

The siliceous bands in the foraminiferal limestone which are referred to by Professor Lawson as "veins" I do not consider such in any true sense of the word; they are more properly cherts or phthanites according to the original use of the terms, but in regard to the great body of siliceous rocks occurring independently there seems to be no use in making a change in terms.

The nature of the so-called "veins" in the limestone seems not to have been clearly understood. On exposed surfaces of many feet in extent these siliceous bands stand out with great distinctness. Some of them are as even and regular as the limestone strata, while others are discontinuous and more uneven. They sometimes blend into the limestone but more commonly are quite sharply distinguished. These bands of chert are contemporaneous deposits, being always conformable to the stratification of the limestone, and differing most markedly from the veins of secondary origin. Thin slides prepared from a number of specimens show them to be thickly filled with organic remains of radiolarian character.

After a description of the jaspers several theories of their origin are considered. The theories are as follows: (1) siliceous springs in the bottom of the ocean, similar to those well known in volcanic regions; (2) radiolarian and other siliceous remains which may have become entirely disssolved in sea water; (3)

volcanic *ejectamenta* which may have become similarly dissolved. The two latter are rejected and the first received, as having the most to support it, in the following words: "The hypothesis of the derivation of the silica from siliceous springs and its precipitation in the bed of the ocean in local accumulations, in which the radiolarian remains became imbedded as they dropped to the bottom, seems, therefore, the most adequate to explain the facts, and there is nothing adverse to it as far as the writer is aware."

Some time since I proposed a theory[1] to account for the origin of the jaspers substantially equivalent to the second given above. Professor Lawson's chief objection to the view of the organic origin of these rocks consists in the fact that they occur in lenticular masses instead of evenly bedded deposits. In his petrographic description it is stated that the "cavities of the radiolaria have been filled with chalcedonic silica and are in definite contrast with the non-chalcedonic matrix." With this last statement my experience is not often in accord. I have found every gradation in the specimens from those in which the radiolaria are distinctly marked, as Professor Lawson says, to those in which they are only faintly distinguishable from the matrix, or apparently absent. In my opinion this state of things gives good ground for the view that, owing to possible transformations through the action of sea water, and the secondary changes which are known to have taken place, there is no valid reason for denying the organic origin even when no organic remains are distinguishable.

Professor Lawson has failed to recognize that the siliceous bands in the limestone must have had an origin similar to those occurring in aggregates by themselves. If the theory of formation by springs is applicable to one it is to the other. The occurrence of these radiolarian jaspers interstratified with the limestone is a most suggestive fact. Similar conditions of sedimentation must have obtained in the one case as in the other, the only difference being that at one time calcareous layers were

[1] Bull. Geol. Soc. Am., Vol. VI, p. 85.

formed, and at another siliceous. The local bands of silica, a few feet perhaps in lateral extent, wholly surrounded by limestone and sharply differentiated from it could not in all probability have been formed through the action of siliceous springs. The large lens-shaped bodies of massive jasper are also abruptly marked off from the inclosing sandstone or shale. If each lens were due to the action of one or more springs the currents must of necessity have been weak near the edges of the deposit and could not possibly be conceived as "sufficient to deflect sediment-laden counter-currents." If sedimentation were going on around the springs it is impossible that the silica could have been precipitated without more or less commingling with the sand. The presence of similar radiolarian jasper in the limestone is suggestive of the view that to whatever cause the lenticular form of the latter is due the same cause conditioned the similar outline of the former.

Turner[1] says of the limestones in the Knoxville at Mount Diablo, and of the older limestones in the Sierras that "each calcareous layer is rather a series of lenticular bodies than a continuous limestone stratum. This applies to the Sierra Nevadas as well, only there the limestone bodies are hundreds of feet in diameter." The belt of foraminiferal limestone described by Professor Lawson is equally bunchy, reaching a very considerable thickness in places, as on the northern slope of Black Mountain, and then contracting to very limited proportions. It thus appears that as far as the shape of the deposits is concerned the spring theory of origin is equally applicable to the limestone.

The statements in the report concerning the condition of the formation of the jaspers do not exactly accord. For instance, on page 426, Professor Lawson says: "If the springs were strong the currents engendered might in some places have been sufficient to deflect sediment-laden counter-currents, and this way serve to explain the general absence of clastic material in the chert." On page 466 he says: "At different more or less pro-

[1] Bull. Geol. Soc. Am., Vol. III, p. 394.

longed periods during the accumulation of the series the bottom of the sea sank sufficiently rapidly to be out of the reach of littoral sediments."

According to the observations of the author the body of the limestone is as free from detrital matter as the jasper, and except for the thickly scattered calcareous remains shows no more traces of organic origin than portions of the jasper.

I cannot see that the origin through springs has anything whatever to support it. It is undoubtedly true that a subsidence or change in ocean currents gave rise to conditions favorable to the accumulation of beds of jasper and limestone. It is, however, rather difficult to believe that this movement, which could not have been of a catastrophic kind, should have accorded exactly with the flow of hundreds, if not thousands, of springs over the sea bottom, which at one period were purely siliceous, and at another deposited nothing but pure carbonate of lime. If the currents were as strong as the author supposes, it does not seem possible that the radiolaria should have settled so thickly as we frequently find them, and besides the springs possibly being fresh would not form a congenial place for marine organisms.

A short discussion is given by the author to deposits which he terms silica-carbonate sinter,[1] the true nature of which seems not to be understood. He says: "Its occurrence in extensive sheets, roughly parallel with the bedding, suggests that it is a contemporaneous deposit, but it may possibly be a vein formation. Its occurrence in the Aucella sandstones elsewhere, and in the San Francisco sandstones of the peninsula is of interest as a possible factor in the correlation of these formations." This is a case in which wider familiarity with the Coast Ranges and their mineral deposits would have readily settled a very simple question. These deposits of sinter are almost always associated with quicksilver ores forming their gangue. The quicksilver deposits are known to date from post-Miocene times, and owing to their recent formation it is to be expected that

[1] Am. Geol., June 1895.

they would occur at all geological horizons. Consequently the correlation of the Knoxville with the Franciscan series (Golden Gate series) by this means is out of the question. The sinter is very similar all through the Coast Ranges, and any deposit is a possible source of quicksilver.

Professor Lawson's discussion of the structure of the older uncrystalline rocks shows, although he minimizes the importance of the disturbances which they have undergone, that it is often difficult of elucidation. The earlier observers have all remarked upon the difficulties connected with a study of the so-called metamorphic rocks, and we cannot admit that all of their work is "superficial." While the author is probably right in asserting that the larger structural features are comparatively simple in the area under discussion, yet it seems to me that there is good reason for believing that the structure is very complex in detail. This is shown by the fracturing and folding of the jasper bands; the frequent occurrence of crushed shale, and thin-bedded sandstone in a ruptured condition; and the presence of innumerable cracks and shear planes in the more massively bedded sandstones. Local areas occur, it is true, totally free from the effects of strain, but they do not dominate. A comparison of the sandstone at Point San Pedro with that north of the valley of the same name affords a good illustration. Both in the cliffs and on top of the point the sandstone weathers out in large blocks in a manner closely simulating the sandstone in the Cretaceous and older Tertiary in the Coast Ranges. On the contrary the similar sandstone in the hills north of San Pedro Valley breaks up in angular fragments; being permeated in many places with veins of quartz and calcite, or linear seamlike cavities. This fracturing and veining is also almost everywhere to be noted in the jaspers and limestone. Professor Lawson considers that because the number of parting planes decreases downward from the surface they are due in great part to atmospheric agencies alone, although he recognizes some shear planes. I believe, however, that we have good reason for holding that a large part of these planes which separate the sandstone into

angular fragments are not due to atmospheric agencies alone, but that they are capable of being produced in thick-bedded rocks as well as in thin-bedded which have not been greatly sheared, but subjected to a rending strain. Such rocks under proper conditions can become recemented and apparently as massive as before. The cracks may thus become completely closed, or left slightly open and filled with calcite or quartz. Subjected to atmospheric agencies lines of weakness are soon developed, and the rock crumbles in angular pieces. A similar rock which has not undergone this breaking strain will weather either in large rounded knobs, or, if it be soft and argillaceous, break up into fragments more or less conchoidal.

Professor Lawson remarks further upon this subject as follows: "The superficial study of this phenomenon has led to grossly exaggerated views as to the amount of disturbance (shattering) to which the Coast Ranges have been subjected. The sharply marked alternation of wet and dry seasons, combined with the treeless character of many of the ranges, is peculiarly favorable t› this disintegration."

It is only necessary to compare the most of the sandstones of the Golden Gate series with those of the Cretaceous or Tertiary to see the vast difference in the manner of weathering. As a result of my experience through nearly the whole of the Coast Ranges, I feel satisfied that peculiarities of climate have not been the cause of the phenomenon under discussion. The abundance of cracks and shear planes in the older rocks is one of the chief reasons why it is so difficult to obtain good building stone from them, although the sandstones are characteristically thick bedded.

I think that Professor Lawson has underestimated the amount of disturbance to which the Golden Gate series has been subjected. It is not necessary for the folds to be involved or intricate, although they certainly are in many places, for it to have undergone a large amount of strain, fracturing, and shearing.

Professor Lawson professes to be entirely ignorant of the

"orogenic movements which effected the deformation and faulting of the Franciscan series" as well as of the relative sequence of these disturbances and the peridotitic intrusions. This is, of course, excusable in one studying only a narrow field where a part of the record is wanting, but too much is at present known of the wider field of Coast Range geology for one to plead ignorance on these questions.

The initial disturbance of the Golden Gate series, with the exception of that produced by the contemporaneous intrusions and flows, dates from the post-Jurassic upheaval. Leaving out of account the serpentine, there is evidence that many of the eruptive bodies associated with this series were subsequently formed. The intrusive nature of the diabase at Hunters point is recognized by Professor Lawson, and he is certainly correct. To the presence of these eruptives, I believe, is to be attributed the extreme disturbance in local areas.

As to the age of the Franciscan series[1] of Professor Lawson nothing more definite is advanced than the evidence of a few imperfect fossils, which cannot be determined specifically and in many cases not even generically. These fossils are supposed to favor the old view of a Cretaceous age. He says: "Evidence, such as it is, is confirmatory of the opinions of Whitney and Becker. . . . . The series as a whole is very probably older than the Knoxville Aucella horizon of California. The writer has no doubt upon this point."

Professor Lawson gives no reason for assuming the series to be older than the Knoxville, and since Mr. Stanton's[2] work places the Knoxville *Aucella* horizon at the base of the Cretaceous, it is difficult to understand how these pre-Knoxville rocks can be included in the Cretaceous.

[1] This designation (American Geologist, June 1895) embraces the same aggregate of strata to which I have given the name Golden Gate series (JOURNAL OF GEOLOGY, May-June 1895) from its characteristic exposures at the entrance to San Francisco Bay. As to which name shall finally be accepted I am, for my part, willing to rest the case, although another claim might with great justice be added, on the truth or falsity of my published statements as to its age and stratigraphic position.

[2] Bull., No. 133, U. S. Geol. Sur.

Again Professor Lawson argues for the post-Jurassic age of the granites in the Coast Ranges, and in order to account for the fact that the pre-Knoxville rocks rest on the granite with a basal conglomerate, he is obliged to assume that they are a part of the Cretaceous. The correctness of one view argues much for the other; if one falls both must be considered invalid.

Again he says: "Fairbanks has combated the views of Whitney and Becker, and has pronounced the series to be of pre-Cretaceous age. He has not yet, in the writer's opinion, established the correctness of his contention." I wish to call especial attention to this statement because of the fact that Professor Lawson has not advanced one particle of evidence in refutation of my published statements as to the existence of a nonconformity between the Knoxville and these lower beds. It is hardly probable that we shall soon find any fossils in good enough condition to be decisive concerning the question at issue, and the main dependence must be placed upon stratigraphy. The fact that these rocks (Golden Gate series) lie unconformably beneath the Knoxville is shown by the most strongly marked contrast, structurally as well as lithologically, in addition to the stratigraphic break which I have described in previous publications.

In closing his description of the stratigraphy and structure of the Franciscan series, Professor Lawson says in regard to the disturbance of the strata: "The most of it seems to have long antedated the uptilting of the Montara fault block, so that the latter differs from most tilted blocks with which we are familiar. These are commonly tilted blocks of strata previously undisturbed, and the tilting is recognized by the attitude of the strata and the presence of fault scarps. In the present case, however, the region has been moderately folded and profoundly faulted with local sharp plication." As far as I am conversant with the geology of California and adjacent parts of Nevada, the fault blocks are commonly not tilted blocks of previously undisturbed strata, but exactly the opposite; that is, the strata have been more or less highly folded and tilted previous to the faulting,

much of which now recognizable, is of quite recent date, geologically speaking.

In the last sentence quoted Professor Lawson seems to recognize quite fully the complicated structure of the Franciscan series.

The serpentine in the area covered by Professor Lawson's report is divided into three linear tracts. One extends across the city of San Francisco from Fort Point to Hunters Point, a distance of ten miles, with a width of one and one-half miles. Another large tract extends from San Andreas Lake to San Mateo Creek, having a length of eleven and one-half miles and a maximum width of one mile.

According to the description these bodies occur as laccolites, laccolitic sills, or dikes. From a careful perusal of the report, and an examination of several of the more important areas covered by these eruptives, I cannot understand the reason for applying to them the designation laccolite. This term was originally given by Gilbert to an eruptive mass which in the course of being forced upward, instead of reaching the surface, finally spread out between the strata, forming a thick lens, and arching them over it in dome form. Professor Lawson is certainly right in the statement that the main bodies are not true dikes, but it seems to me that the term sheet or sill which he uses quite frequently is the really proper one for these eruptives. If the term laccolite has any exact meaning it is certainly not synonymous with sheet or sill.

I have carefully examined the so-called laccolites of Hunters Point, Potrero and Fort Point and can find no evidence that these eruptive masses were ever covered by an arched roof. In my opinion the field relations indicate that they cooled as sheets or dikes. They have no appearance of being lens shaped, and if it is true, as Professor Lawson supposes, that they are all connected through the distance of ten miles, we have then a long sheet inclined at an angle of 35° to 40°; and though in a general way intruded along the bedding planes of the sandstone and shale, yet, owing to the marked irregularities of the surface of the erup-

tive sheet, the inclosing strata have been much disturbed and show locally a marked variation in strike and dip.

The remnant of a supposed laccolite roof on Hunters Point I would interpret to be a body of jasper and sandstone or shale inclosed in the serpentine, as a portion of it occupies a sag between higher serpentine ridges, and apparently extends down into a small ravine.

It is fully as difficult to believe that the Fort Point occurrence is a laccolite. The stratum of shale, sandstone, and occasional bodies of jasper, which appears in the cliffs and along the beach south of the fort, dips into the cliffs at an average angle of not less than 30°, and it seems to me that it can be nothing else than an inclusion between two sheets of serpentine.

The exposures at the Potrero are good and bear out the opinion which I have already expressed.

That the two dominant ridges, Montara Mountain and San Bruno Mountains, are fault blocks of such importance, or their diastrophic history so clear as Professor Lawson outlines it, does not seem evident to me. The San Bruno Mountains are said to be the older block, but the southern slope facing the supposed fault is remarkably bold and steep, not showing an advanced stage of degradation, and in addition the northern slope is almost as abrupt. The supposed fault of 7000 feet appears almost incredible, and it does not seem at all necessary to postulate it in order to account for the position of the Merced series. That this series should once have existed over the whole of the northern end of the San Francisco peninsula appears very problematical at least. That a series over a mile in thickness, and of so late an age, should have been so completely removed as not to leave a trace north of the supposed fault it is not easy to believe.

I cannot find any evidence either of the supposed great fault on the southern slope of Montara Mountain. The topography as a whole does not support the idea, and that the ridge is a simple tilted block is not supported by the evidence which Professor Lawson adduces of important faults on the northern slope. Professor Lawson's suggestion in another place that Montara Moun-

tain has been forced up through the strata in the manner of a telescopic thrust appears to me to have an important element of truth in it. This thrust probably resulting from lateral compression produced the elevation of the granite, partly, at least, through shearing.

It would appear that the evidence in favor of the successive appearance of the "two dominant fault blocks" is exceedingly slight. While the San Bruno Mountains are considered to have been above the sea level and the Pliocene undergoing erosion, there is believed to have been no such subaërial period for Montara Mountain until the final uplift resulting in the terrace deposits. This is opposed to the observation of Mr. Ashley[1] as well as to my own views concerning the general post-Pliocene elevation of the coast. By this elevation I do not mean that to which the terraces are due, but an earlier one resulting from the same influences which deformed the Pliocene sediments the whole length of the California coast.

In regard to the age of the granite Professor Lawson[2] says: "The simplest and most natural hypothesis that suggests itself is that the granite corresponds in age with that of the Sierra Nevada, and this hypothesis has not yet been exhausted of its strong probability of truth. The granites of the Sierra Nevada, in so far as their age is known, are clearly post-Jurassic. Granites of about this age are extensively developed along the west coast of North America from Alaska southward. The granites of the southern and northern Coast Ranges seem to be geologically continuous with those of the Sierra Nevada. The fact that the Sierra are separated from the Coast Ranges by the valley of California is immaterial to the discussion, since the latter is clearly a delta-filled geosyncline of late Tertiary or post-Tertiary origin. There is therefore a strong presumption in favor of the view that the granites of the Coast Ranges and those of the Sierra Nevada are of common origin and common history. This presumption must be steadily kept in view till it is negatived by positive evidence."

[1] Neocene Stratigraphy of the Santa Cruz Mountains, p. 334.

[2] Am. Geol., June 1895.

It does not seem to me that there is any validity whatever in the above reasoning, and in the light of the true position of the Golden Gate series there is a strong presumption in favor of an opinion exactly opposite to that just quoted. In fact the presumption is so strong that it amounts almost to a certainty that the granite in the Coast Ranges is older than the main body of the granite in the Sierras. What we at present know of the position of the Golden Gate series points to the fact that its first upheaval was contemporaneous with the last great upheaval recorded in the rocks of both the Sierras and Klamath Mountains. The Mariposa beds involved in this upheaval in the Sierras are held to be Upper Jurassic. The Knoxville beds deposited after this upheaval are believed on the best authority to be Lower Cretaceous; and if we make the granite in the Coast Ranges the same age as that in the Sierras, we must crowd into the break between the Mariposa beds and the Knoxville, a series of beds thousands of feet in thickness and separated from the Knoxville by a break as profound as that between the Knoxville and the Jurassic.

There is every reason for assuming that the granitic rocks of California are not all of the same age. Granitic bowlders occur in the Mariposa beds south of Colfax, a fact pointing to a pre-Jurassic granite body in that region.

The youngest fossiliferous rocks associated with granite in southern California are probably of Carboniferous age, and while the extension of the crystalline basement rocks of that region northwestward into the Coast Ranges is not likely to be much younger than the Carboniferous, for all that we know at present it may be much older.

HAROLD W. FAIRBANKS.

BERKELEY, CALIFORNIA.

EDITORIAL.

THE success of the recent meeting of the Geological Society of America was undoubtedly due to the fact that it was held in Washington. No other city in the country offers so many attractions to geologists in the winter time as the national capital. Containing as it does the largest body of geological investigators to be found in any one place in the world, it has become a center of geological activity and the repository of many valuable collections. Located within easy reach of the universities of the East and South and of the Middle West it has become a favorite rendezvous for geologists scattered throughout these parts of the country. For these reasons the suggestion made by Mr. Walcott, Director of the United States Geological Survey, that the society hold all its winter meetings in Washington and its summer meetings elsewhere, is an excellent one, and was heartily endorsed by the retiring president, Professor Le Conte. Since the present method of entertaining the society would prove a burden upon the Washington members if repeated annually, it would be proper to allow the visiting members to share the expense by dividing the cost *per capita*. It is to be hoped that the proposition to meet annually in Washington be considered seriously by the society.

The necessity of more expeditious methods of conducting the presentation of papers and the need of a livelier sense of obligation to fellow-members on the part of those misusing the time of the meeting were apparent. It ought not to require long reflection to convince one that beyond a reasonable use of time the tax on the patience of an audience defeats the object of an address, and is more than a waste of energy.

It is to be noted that the present unsatisfactory process of

conducting the annual election resulted in the only regrettable incident connected with this otherwise highly successful meeting. The present method should be changed speedily. It has been suggested that a process should be adopted by which the secretary should send to every member blanks for nominations for each officer; each member to nominate one person for each office. Upon receiving these nominations the secretary should ascertain those having the two highest numbers of nominating votes, and mail to each member a ballot placing these in nomination, and requesting a vote.

The extent of the interest taken in the meeting is shown by the number of papers presented, which reached forty-nine, and by the fact that discussions were quite generally participated in. The presence of ladies at the banquet and the efforts of the committee on entertainment and those of the toastmaster, Professor Emerson, combined to render this feature of the meeting most enjoyable. J. P. I.

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In the October-November number of the Journal of Geology (p. 811) Mr. J. B. Tyrrell's paper on the "Genesis of Lake Agassiz" includes incidental reference to the application of the name "Laurentide Glacier," upon which it may be useful to make some comment. When it had been shown by the writer that the Cordilleran ice-sheet of the West was self-contained, it became evident that the great eastern division of what had previously been referred to as a "continental glacier" required some distinctive appellation. The name Laurentide glacier was then proposed in the following terms: "Recognizing, however, the essential separateness of the western and eastern confluent ice-masses, and the fact that it is no longer appropriate to designate one of these the 'Continental glacier' the writer ventures to propose that the eastern *mer de glace* may appropriately be named the *Laurentide glacier* while its western fellow is known as the *Cordilleran glacier*."[1] Thus it appears that the

[1] American Geologist, Sept. 1890. See also Trans. Royal Soc., Canada, Vol. VIII, Sec. IV, p. 56.

term Laurentide glacier was intended to designate an ice-sheet developed upon the entire Laurentian plateau or protaxis—the Canadian shield of Suess—which extends itself, as a relatively elevated tract of U-shaped form around the depression of Hudson Bay, from Labrador on the east to the Arctic Ocean near the mouth of the Mackenzie on the west.

Mr. Tyrrell's investigations relate particularly to that arm of the protaxis which lies to the west of Hudson Bay, and upon the northern part of this he has been able to define a center of dispersion of glacier-ice to which he has applied the name "Keewatin glacier." He suggests that the name Laurentide glacier may now be relegated to the similar center of radiation of ice shown by Mr. A. P. Low to have existed on the Labrador peninsula, and supposes that ice from the latter gathering-ground (at a date subsequent to that of the greatest spread of the Keewatin glacier) crossed the southern part of Hudson's Bay to the Winnipeg basin as well as to that part of the continent in the vicinity of the Great Lakes. It is, however, tacitly assumed that no general occupation of the Laurentian plateau by glacier-ice occurred at a period antecedent to that in which the Keewatin glacier became defined; although, to the writer, it seems probable that at one time this plateau or axis was thus covered by ice in all its length and that this ice moved down from higher to lower levels in conformity with the normal slope in all directions.

A second assumption (to which, however, several writers on this subject besides Mr. Tyrrell have given credence) is that implied in the suggested passage of glacier-ice originating in the Labrador region across the watershed to the north of the Great Lakes. The actual evidence on this point appears to the writer to be slight and inconclusive in its nature. Our knowledge of the rocks of the great region involved is, it is believed, insufficient to prove that any erratics from the basin of Hudson Bay have actually crossed this watershed to the south or southwest. Nor can the observed directions of striation be taken as definitely indicating ice-movement in a southerly sense in all

cases, for at the time of observation of many of these, it cannot be doubted that a southerly rather than a northerly motion was naturally assumed, in consequence of hypotheses then unquestioned, and without the critical examination called for in view of later discoveries. So great an extension of an ice-sheet originating on the Labrador peninsula, is all the more doubtful in the light of Mr. Chalmer's investigations, which show that no glacier-ice from the northward crossed the highlands to the south of the St. Lawrence below Quebec. These highlands developed in New Brunswick and northern Maine, an independent center of dispersion, which Mr. Chalmers suggests may be referred to as the Appalachian system of glaciers or the Appalachian glacier.[1] If, therefore, we may admit the existence of a Laurentide glacier of early date and such as to envelop the whole Laurentian plateau, the Keewatin glacier of Mr. Tyrrell, with that which may be named the Labradorian glacier,[2] as known to us by Mr. Low's work, may be regarded as relatively local (although still very important) centers of dispersion connected with a diminishing stage of the glacial period. In this case the overriding of the area at one time covered by the southward extension of the Keewatin glacier by ice from the eastward (as demonstrated by Mr. Tyrrell) may be attributed merely to a still later reëxtension, due to climatic changes, of that part of the Laurentide glacier situated to the east of Lake Winnipeg. If, on the other hand, it should ultimately be shown that no continuous ice-sheet ever covered the entire length of the Laurentian plateau, the several great glacier masses actually known to have been developed upon these highlands may still be appropriately considered as constituting together a Laurentide group, as distinguished from the great western Cordilleran ice-mass.

In the case of the Keewatin and in that of the Labradorean glacier, it has been shown by Messrs. Tyrrell and Low that the centers of dispersion changed, giving rise to superposed series of striations, and it appears probable that in the study of this

[1] American Geologist, Vol. VI (1890), p. 325.

[2] This has, I believe, already been proposed by Mr. F. B. Taylor.

migration of gathering-grounds of glacier-ice on the Laurentian highlands, the explanation of many otherwise anomalous circumstances will yet be found. Any inquiry into the causes of such migration opens a wide field of discussion, including particularly meteorological and possibly changed orographical conditions. Other things being equal, it is obvious that the places in which the accumulation of glacier-ice began would also in all probability be those where the last centers of its dispersion continued longest and ultimately failed. It is very important to trace the migration of these centers from which the ice flowed, and if possible to ascertain the conditions which, in all probability, may have interfered with the coincidence of the initial radiant areas and those marking the close of the epoch of glaciation.

G. M. D.

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It would appear from the papers of Professors Tarr and Barton read at the recent meeting of the Geological Society at Washington, abstracts of which appear in this number of the Journal, that Professor Salisbury and myself must have invited misinterpretation of our views respecting the former extension of the inland ice-sheet of Greenland by infelicities of expression not altogether evident to us. What we have thus far published has consisted, in the main, of brief statements intended rather to show the bearing of the topography of the coast upon the larger questions of glacial prevalence than to indicate the precise local extension of the ice. In the series of papers entitled "*Glacial Studies in Greenland*" (not yet complete, having been interrupted to give earlier place to contributions awaiting publication), the specific subject of former glacial extension has not yet been reached. When it shall be, however, we shall not wish to be understood as attempting to map the precise limit of former glaciation on the thousand miles of borderland along which we coasted, but merely as endeavoring to indicate its general limitations. We believe, neverthless, that our observations and inferences are thoroughly trustworthy in the general sense in which they are intended to be received, and that they are decisive in

their bearing upon two general hypotheses of wide interest; the one, that the ice-cap of Greenland formerly stretched across Baffins Bay and Davis Strait and became the source of the mainland ice-sheet; the other, that, in a former supposed state of elevation, the ice-cap pushed out into the heart of Baffins Bay or into the Atlantic until it reached adequate conditions of wastage by flotation or by low-level extension. In either case, the borderland of Greenland must, presumably, have been effectively glaciated for a long period, and should manifest this in the subjugation of its topographic contours. In its bearings upon these general problems, an advance of a few miles, more or less, an ineffectual overtopping of a few heights, more or less, are relatively inconsequential. Our language is to be interpreted in the light of the major questions whose solution we sought.

There does not appear, however, to be any essential lack of harmony between the data of Professors Barton and Tarr and the interpretations of Professor Salisbury and myself, unless it be in relatively unimportant details. Professor Salisbury makes the following statement relative to the region (this JOURNAL, Vol. III., pp. 876–7):

> On the whole, judging from topography alone, it seemed more probable that the coast from about latitude 70° north to the end of the Nugsuak peninsula [the southern one] had not been recently smothered in ice, though it is well possible that the ice-cap may have once extended beyond its present limits, and that isolated glaciers occupied the valleys leading down to the sea. The northwest end of the peninsula bears the marks of the passage of ice over a considerable part of the coastal front. North of Nugsuak peninsula, and from that point to the south side of Melville Bay, the topography of the coast, so far as seen, indicated general, though not universal, glaciation. Thus the southwestern end of Svarten Huk peninsula (71° 30′) has a topography denoting the absence of glaciation.

This embraces both of the districts in question.

Relative to the region of Professor Barton's studies, I made the following (unpublished) note on July 18, 1894, at the conclusion of detailed notes on Hare island, the Nugsuak peninsula, (the one south of Umanak fiord), Ubekyendt and Upernivik islands, Svarten Huk peninsula, and Disco Island:

I infer that the inland ice once pushed out into Baffins Bay through the Waigat and through Umanak fiord and overlapped the adjacent lands, but did not overtop the highest parts of Disco, Upernivik and Ubekyendt islands and Svarten Huk peninsula. The ice border rose 2000 feet above the present sea surface, but probably not 3000 feet on the coastal line, quite certainly not 4000 or 5000 feet. I have traced on the chart a theoretical outline of the farthest ice. This of course does not include local ice on the uncovered land. It, on the contrary, presumes it.

This hypothetical line starts with the northwestern part of Disco Island and swings outside of Hare island and some distance off the extremity of Nugsuak peninsula, touches the outer side of Ubekyendt Island, and thence connects with the southern portion of Svarten Huk peninsula. The outer curve of this line is *sixty miles away from the present border of the inland ice* and embraces the entire territory of Professor Barton's special studies, as I understand them.

I have no notes on the northern Nugsuak peninsula which was the special field of Professor Tarr's studies, the Falcon having turned away from the coast somewhat south of it to attempt the "middle passage" of Melville Bay, and, failing in this, returned to the vicinity of the coast a little north of the peninsula. On the region next south I made the following note on July 19:

With the exception of Sanderson's Hope and a few other prominences south of it, the whole region shows rounded contours, so far as seen. The small islands are well-rounded domes of rock that appear entirely bare. I could not detect any bowlders or other débris upon them. They are simple *roches moutonnées*, but not strikingly typical as such. The reduction has not completely subordinated them to glacial types. I have no doubt the ice pushed out well into the bay here. Some of the higher peaks may have remained as nunataks.

These small islands are rather farther away from the edge of the inland ice than the similar ones described by Professor Tarr.

It appears, therefore, that we explicity recognized predominant glaciation reaching out from 30 to 60 miles, and trespassing on the borders of Baffins Bay, and that we excepted only some of the higher points. It is only by demonstrating that these were submerged by the inland ice that any notably greater

extension can be established, and the most of these points were not visited by the members of the recent expedition, nor were comparable heights of like situation near the coast line studied. Sanderson's Hope is charted as 3467 feet; a point on Svarten Huk peninsula, as 5230; a point on Disco Island as 5110, and many other points range from 3000 feet upwards. At most, therefore, the differences between us are merely matters of minor detail so far as observational determinations are concerned.

This advance of 30 to 60 miles seemed to one party to call for expressions of amplitude, to the other, instinctively making comparison with the many hundreds of miles of ice invasion of the mainland, to call for diminutives. Here is, indeed, a wide *psychological* difference, and we can contribute nothing to minimize this difference. Under the widest permissible interpretation of the facts as seen by either party the advance seems to us emphatically small, and very significant in its smallness.

The reliefs of the region seemed to the earlier party to belong to the semi-subdued type. The later party appear to have supposed them to represent the *unsubdued* type of the earlier party. The determinations of the later party are, however, in close accord with the classification of the earlier party.

It is possible that Professors Tarr and Barton unconsciously transferred to this region our rather emphatic descriptions of certain markedly serrate tracts farther south, and of certain ragged islands lying to the north, *e. g.*, Dalrymple Island (figured in this JOURNAL, Vol. II, p. 661), and Cone Island (Fig. 1., Vol. III., p. 772). As indicated above, we did not class the topography of the region in question under the markedly ragged and serrate type but under an intermediate one of partial subjugation. The figures referred to illustrate our standard of the former class. The courteous suggestion that the differences of interpretation were due to our point of view on the leeside of the prominences is inapplicable to the important case of Disco Island, for Professor Salisbury passed on the stoss side. It is only measurably applicable to the rest of the territory, as the

oblique views of approach and retreat gave traversing lines of vision that partially reached the stoss contours.

This rather extended note has its purpose in a desire to make clear the narrow limits of such differences of observation as may exist and to show that the two main questions of general interest are essentially unaffected by them. Glacialists may feel sure that the conclusions derived from the topographic study of a thousand miles of the coast, even though cursory, and limited by conditions, will be found decisive on the main issues.

T. C. C.

REVIEWS.

Manual of Determinative Mineralogy, with an Introduction on Blowpipe Analysis. By GEORGE J. BRUSH. Revised and enlarged by Samuel L. Penfield. New York: John Wiley & Sons, 1896.

Since its first appearance in 1874, Brush's *Determinative Mineralogy and Blowpipe Analysis* has filled the demand for a text-book in this science almost to the exclusion of others. The tables, especially, proved to furnish an exceptionally ready and accurate means of identifying mineral species. The use of the book has of late years, however, been confined largely to the tables, since its opening chapters, while valuable for reference, were hardly adapted for class instruction, if, indeed, they were intended to be so used. This lack in the book Professor Penfield has most satisfactorily filled in the new form in which he now presents it. In its present form it furnishes not only a complete text-book for class use, but also a work which should enable even the novice without further aid to gain a practical knowledge of determinative mineralogy.

Opening with a statement of the chemical principles especially applicable to mineralogy, for the author remarks that mineralogy is chiefly a chemical science, the next chapter treats, with excellent illustrations, of the apparatus and reagents to be employed and of the nature and uses of flames. Several new experiments incorporated here add much to the value and interest of the chapter.

In the following chapter the reactions of the elements, arranged in alphabetical order, are given with great fullness, while carefully described experiments show how many of the typical reactions can be obtained. Every detail is here given with a care and precision that might at first sight seem superfluous, but the necessity for each, Professor Penfield, it may be believed, has fully proved in his long experience as a teacher of the subject. The student will at least be impressed with the need of care and accuracy in making the tests and will not be led to

expect satisfactory results if they are not so performed. If there be any criticism to be made of this portion of the work it is to wish that more mention had been made of possible interfering elements, for the field mineralogist rarely has cabinet specimens to deal with.

In the next chapter the blowpipe and chemical reactions are tabulated in a form which will be recognized as a distinct improvement on those of the earlier book. The tables are models of clearness and completeness. With an introduction to the use of the tables, the revised portion of the work closes, but promise is made of an early revision of the tables, including the introduction of new species and many changes and corrections in the chemical formulæ. To express the hope, which will be general, that this promise may soon be fulfilled, is to bestow the highest praise on the work which has been already done.

O. C. FARRINGTON.

The Dinosaurs of North America. By OTHNIEL CHARLES MARSH. Sixteenth Annual Report of the United States Geological Survey, Part I, pp. 133–414.

Under this title Professor Marsh has published, in an article of 101 pages of text, a résumé of his long series of papers on the Dinosauria of North America. Intended as it is for the general reader, there are few new facts brought out, and the specialist finds little of value to himself beyond the convenience of a condensed statement of Professor Marsh's views, and the large collection of illustrations which form so important a part of the paper. There are eighty-four plates and sixty-six figures in the text. Most of the plates are familiar to the readers of the *American Journal of Science*, as they are enlarged copies of the ones accompanying the author's papers in that journal.

The author's aim is "to give the general reader a clear idea of some of the type specimens of one great group of extinct animals that were long the dominant forms of life in this continent." Of especial interest to such a class must be the restorations attempted by Professor Marsh, and it is well to issue a warning against receiving as entirely accurate restorations which, made in many cases from incomplete material, can only represent the author's idea of the most probable form of the skeleton. In the same spirit of warning we must call attention to the statement that "the best authorities regard them (the Dinosauria) as constituting a distinct subclass of Reptilia;" indeed, it should be

remembered that some of the "best authorities" are among those who assert "that these reptiles do not form a natural group, but belong to divisions remotely connected and not derived from a common stock." It is, to say the least, a very open question whether the groups defined as the orders *Theropoda*, *Sauropoda*, and *Predentata* are not distinct and unrelated.

The Dinosaurs are discussed in the order of their appearance in time. The Triassic Dinosaurs come under Part I and are followed by the Jurassic and Cretaceous forms in Parts II and III. These parts are confined to descriptions of the anatomical characters of the various forms and their distributions. The author discusses briefly in this connection the European forms and their relations to the North American forms.

Part IV is taken up with a general discussion of the relationship of the Dinosauria to the Aëtosauria, Crocodilia, Belodontia, and Aves, to all of which groups he finds many points of similarity.

Part V is devoted entirely to a classification of the group which he regards as a distinct subclass *Dinosauria*, with three orders *Theropoda*, *Sauropoda*, and *Predentata*. The order *Theropoda* contains ten families and the four suborders *Cœluria*, *Compsognatha*, *Ceratosauria*, and *Hallopoda*. The order *Sauropoda* contains six families and no suborders. The order *Predentata* contains eleven families and the suborders *Stegosauria*, *Ceratopsia*, and *Ornithopoda*.

Professor Marsh has retained the opinions which he has expressed in his former publications on the same subject, many of which have been criticised and controverted in current scientific literature, so that, while the work will find its chief, and a great value, to the reader who has not access to scientific periodicals, he must not lose sight of the fact that the taxonomic position of the animals comprising the heterogeneous group called Dinosaurs is still an unsettled question.

E. C. C.

ABSTRACTS.

PAPERS READ AT THE WASHINGTON MEETING OF THE GEOLOGICAL SOCIETY OF AMERICA.

Glacial Observations in the Umanak District, Greenland. By GEO. H. BARTON.

A party consisting of six persons under the direction of Professor Alfred E. Burton, of the Massachusetts Institute of Technology, was landed by the Sixth Peary Expedition at the village of Umanak, Lat. 70° 30′, on an island in Umanak fiord, August 5, 1896. On September 9 the party was again taken on board for the return home. Between these dates observations were carried on upon the marginal area of the continental ice-cap to a distance of fifteen miles inland, and upon the glacial tongues passing down from the ice-cap by the various valleys leading into the Karajak and Itivdliarsuk fiords.

The region of the Umanak District was selected for investigation because of the facilities offered for much to be seen in the short time at the disposal of the party. Easy access to the edge of the inland ice by means of the larger fiords, the many glaciers large and small descending near or into the waters of the fiords, the great number of icebergs constantly passing out into the open waters of Baffin's Bay, and finally the fact that this region had not been visited by Americans, caused the selection.

Access to the surface of the inland ice was obtained from the nunatak lying between the Greater and Smaller Karajak glaciers. Considerable difficulty was encountered in getting upon the surface owing to the precipitous, generally vertical, sometimes overhanging character of the edge, rising from ten to forty feet. In only three places for a distance of over twenty miles did the edge present an inclined surface sufficiently gentle in slope to allow of ascent or descent.

In attempting to pass inland upon the ice the crevassing of the Greater Karajak glacier was found to extend far backward so that our course had to be deflected for several miles and finally to pass along the neutral ground between the two Karajaks. The elevation of the

ice surface where first reached was about 1500 feet above sea level, while our fartherest point inland was about 2950 feet in elevation.

For a distance of about two miles the surface of the ice is very rough, consisting of a series of billows, very much like a frozen short, choppy sea. Over this it was very difficult to drag the sledge which constantly upset. This area was also full of dust holes from the size of a pencil to three feet in diameter and an average depth of about two feet. These were filled nearly to the surface with water and had a layer of dust in the bottom, an inch or two in thickness.

Beyond this we passed through a crevassed area for two or three miles and then came to a broadly rolling, undulating area which stretched away as far as the eye could reach looking like the American prairies in winter. The surface here was hard and crisp so that walking was very easy.

One lake was seen with several small streams flowing into it and one large stream flowing from it toward the land. Small streams were constantly encountered except in the crevassed area all flowing toward the land or toward the lake. One large stream, twenty to thirty feet across, and twenty to twenty-five feet deep, including five feet of water, was found at the farthest point reached flowing directly away from the land toward the interior.

No detritus was found on the inland ice except the dust in the dust hole area. Outside of this area the water of the streams was clear and their channels showed only clear ice.

The two important glaciers studied were the Greater Karajak and the Itivdliarsuk glaciers. The first of these has a width of about five miles and a length of from ten to fifteen miles from the edge of the inland ice to the waters of the fiord at its frontal face, but the crevassing of its current passes backward several miles into the mass of the inland ice. The elevation of the surface of the glacier as it first leaves the margin of the inland ice is about 1500 feet above sea level while directly at its frontal face it is about 500 feet. This gives a gradient of about 1000 feet in a distance of about ten miles, or 100 feet to the mile.

The rate of motion was carefully studied by Professor Burton during a period of nearly thirteen days. The result showed that there was an eddy in the ice at the point where the observations were made, as the ice near shore was moving slightly upstream. At a distance of 1708 feet it was stationary, while at a distance of 3396 feet the motion amounted during this time to 30.20 feet or 2⅓ feet per day. Up to this distance stakes had been set in the ice. At a distance of 2.4 miles a

peculiarly shaped pinnacle furnished a point of observation. This was found to move during the same time a distance of 236 feet or about 19 feet per day.

This was the only case in which the actual rate of motion was determined. The Itivdliarsuk, three miles in width, was crevassed completely to the shore margin so that it could not be traversed with any safety, and no attempt was made to determine the rate of the smaller ones. Neither of these large glaciers carry any detritus either superglacial or englacial, except in the case of the Itivdliarsuk. Small nunataks near its source furnish two medial moraines which can be traced nearly throughout its length on the surface but are largely incorporated as englacial material before reaching the terminus. The edge of the larger glaciers like that of the inland ice is almost always nearly vertical with a height of from ten to forty. The structure is distinctly banded usually, apparently due to a shearing of the upper portions over the under from the central portions of the stream shoreward, the layers being inclined away from the shore.

Lateral streams flowing along the margin often cut caverns into the ice by means of which opportunity is furnished to study subglacial action. Small bowlders caught between larger ones or between a larger one and a projecting ledge are often broken into small fragments or ground to powder. In the case of rapid motion of the ice, distinct vacant spaces are left between the lee of a boss of rock and the ice, but where the motion is slow the ice is kept pressed against the lee side of the boss taking on a fanlike structure as it is pressed downward.

Lateral moraines along the sides of the glaciers are always present. They consist of a mixture of angular, subangular and rounded fragments, usually with considerable sand and a little clay, and occasionally largely made up almost entirely of till-like material.

From the edge of the inland ice and also from the detached ice-caps of the Nugsuak peninsula a large number of smaller glaciers descend the more or less narrow gorges, some reaching sea level and discharging icebergs, but the majority terminating from 100 to 1000 feet above the sea. The gradient of descent varies strongly in the various ones. In some it is very steep, in some very gentle, while many have a great change in various portions of their own length.

With two exceptions all the glaciers show evidence of diminution in length and depth, in older terminal moraines and glaciated surfaces farther down the valleys and older lateral moraines higher up the sides.

The two exceptions, near Sermiarsut on the Nugsuak peninsula seem to be overriding terminal moraines of not great age but these were seen toward the last of my work and were not carefully studied.

Everywhere throughout the regions visited there is evidence of the former greater extension of the inland ice, it having covered all the highest peaks, passed out over the ends of the promontories, filling the fiords and passing into the waters of Baffin's Bay.[1]

The peaks which present sharp serrated edges toward Baffin's Bay are distinctly rounded on the sides toward the inland ice; the highest points visited show abundant roche moutonnée forms, and everywhere erratics are freely scattered.

The Origin and Relations of the Grenville and Hastings Series in the Canadian Laurentian. By FRANK D. ADAMS and ALFRED E. BARLOW, with observations by R. W. Ells.[2]

This paper may be regarded as a continuation of two former papers[3] by Adams, treating of the Laurentian of Canada and presenting the results of further work. It deals more especially with the probable origin of the Grenville series in the light of recent studies by the authors of a very large Laurentian area in central Ontario, along the margin of the protaxis and north of Lake Ontario.

The northwestern portion of the district in question is underlain by the Fundamental Gneiss, which is believed to form part of the original crust of the earth and to be of igneous origin. The southeastern portion is occupied chiefly by the thinly bedded calcareous rock of the Hastings series, a series of undoubtedly sedimentary origin, but of unknown age, separated, however by a long erosion interval from the overlying Cambro-Silurian, and having certain petrographical resemblances to the Huronian of the typical area north of Lake Huron. Between these two series of rocks is an irregular belt of the Grenville series, identical in all respects with that of the original Grenville area in the province of Quebec. The character of these several series is described and their resemblances and points of difference indicated.

[1] See paper by writer in American Geologist, Vol. XVIII, pp. 379–384, 1896.

[2] The paper appears in the American Journal of Science for March 1897.

[3] Ueber das oder Ober Laurentian in Canada. Neues Jahrbuch für Mineralogie. Beil. Bd. VIII, 1893.

A Further Contribution to our Knowledge of the Laurentian.—Am. Jour. Sci., July 1895.

The Grenville series differs from the Fundamental Gneiss in that it contains certain rocks whose composition marks them as highly altered sediments. These rocks are in part limestones and in part certain peculiar gneisses, rich in sillimanite and garnet, having the composition of shales, or very rich in quartz and passing into quartzite, having thus the composition of sandstones. These rocks, as has been shown in one of the papers above referred to, usually occur in close association with one another, and are quite different in composition from any igneous rocks hitherto described. These rocks it is which are considered as characterizing the Grenville series. They usually, however, form but a very small proportion of the rocky complex of the areas in which they occur, and which, owing to their presence, are referred to the Grenville series. They are associated with, and often enclosed by, much greater volumes of gneisses and amphibolitic rocks, identical in character with those of the Fundamental Gneiss. The limestones are also almost invariably penetrated by great masses of coarse pegmatite, and in some cases large bodies of the limestone are found imbedded in what would otherwise be supposed to be the Fundamental Gneiss. The whole thus presents the character of a series of sedimentary rocks, chiefly limestones invaded by great masses of the Fundamental Gneiss, and in which possibly some varieties of the gneisses present may owe their origin to a partial admixture of sedimentary material with the igneous rocks by actual fusion. There is, however, no reason to believe, from the evidence at present available, that any considerable proportion of the series has originated in the last mentioned manner.

From the relations of the several series, as displayed in central Ontario, it is believed that the sedimentary portion of the Grenville series is but a modified part of the Hastings series, that in fact the present relations of the Grenville series are due to a commingling of portions of the Hastings series with the Fundamental Gneiss along their line or zone of contact. The Fundamental Gneiss upon which the Hastings series was originally laid down having at a subsequent time been softened by the influence of heat, and having under the influence of dynamic action eaten into and fretted away the overlying Hastings series, giving rise to an intermediate zone of mixed rocks which constitutes the Grenville series. The relations of the two series being thus very similar to that shown by Lawson and Barlow to exist between the Huronian and the Fundamental Gneiss in the districts about Lake Superior and Lake Huron.

The appended remarks by Dr. Ells deal with the district to the east and northeast of that studied by Adams and Barlow, and show that here also the same series can be recognized and that the same relations between them obtain.

The Origin and Age of the Gypsum Deposits of Kansas. By G. P. GRIMSLEY.

Among the minerals of economic importance in the state of Kansas, gypsum occupies a prominent place, and it has attracted the attention of geologists for many years. At the present time the state stands first in the Union in value of its gypsum product. The deposits of ecomic value occur in a belt trending northeast–southwest across the state with a length of 230 miles and in width varying from five miles at the north to thirty-six miles near the southern line. There are three important areas: northern, central, and southern. Intermediate deposits connect the northern and central areas, while the interval between the central and southern is occupied by salt beds. The topography increases in ruggedness southward. In the northern area three companies are engaged in plaster manufacture. There are six mills in the central area, and two in the southern. The rock is white or a gray mottled, with a saccharoidal texture in the upper portion, but becomes more compact below. The dip is toward the west. In the central area occur a number of secondary gypsum dirt deposits, which form the basis of the greater portion of the plaster manufacture. This material is a granular dirt of an ash-gray color. It is soft, and readily shoveled into cars, so that it is ready for calcining with less labor and expense than in the case of the solid gypsum. At the present time four of these deposits are worked. Under the microscope the dirt is seen to consist of a mass of small angular gypsum crystals of varying size. Mingled with the gypsum crystals are small quartz crystals, some calcite poorly crystallized, and traces of organic material. The deposits are found in low, swampy ground near small creeks, and strong springs occur in most of them. Usually there is a ledge of rock gypsum at the same level, or ten to twenty feet below. The gypsum beds are all Permian, ranging from the Neosho epoch to the close, and they rise geologically to the south. The northern and central rock gypsum deposits appear to have been formed in the same gulf cut off from the western Permian sea; while the gypsum dirt

deposits are secondary and of recent age. The southern deposit was formed in a shallow gulf cut off from the Permian sea at a later period not far from the close. Salt appears to have been deposited with the gypsum, but now it is only found farther out in the old gulf where it was thicker.

The Cornell Glacier, Greenland. By RALPH S. TARR.

In this paper attention is called to the recently published conclusions of Professors Salisbury and Chamberlin that glaciation on the Greenland coast has not in recent times extended much further than the present ice margin. The evidence upon which this is based is stated, and it is pointed out that another interpretation of the rugged topography of the high parts of the Greenland coast is possible. This is, briefly, that the peaks seen from a passing vessel present the face which is least likely to be glaciated; also that they have been longer exposed to denudation, both preglacial and postglacial, and that, being higher than the surrounding land, they were more rugged before the ice came, and reaching up into the glacier they were less scoured by the ice than is the case with the lower lands.

The description of the geological conditions and evidence of glaciation upon the Upper Nugsuak peninsula (latitude 74° 10′–15′) follows, and it is pointed out that the higher points in this region have all been covered by ice notwithstanding the fact that, as seen from the sea, the topography of the peaks is as rugged as that of other parts of the Greenland coast. Small beds of till and numerous transported pebbles, whose origin is somewhere within the ice-sheet, are found on the highest points. The Devil's Thumb, rising 2650 feet above the sea, has been glaciated; Wilcox, 1400 feet high, and twenty-five miles from the margin of the ice, has also been ice covered, and the glacier has extended over the Duck Islands, which are eight or ten miles further to sea than this. Adding to the land height the depth of the water in the neighboring bays, it is certain that at the Devil's Thumb the ice-sheet was not less than 3000 feet thick; that at Wilcox Head, twenty to twenty-five miles from the present ice margin, there was glaciation to a depth of certainly not less than 2000 feet, and that at the Duck Islands, thirty or thirty-five miles from the present glacier, the ice-sheet had a depth of not less than 600 feet. In other words, in this part of the Greenland coast all the land now visible has been recently glaciated, and so far as evidence here is concerned, there is no

reason to place a limit to its advance. The presence of shells in a recently abandoned moraine, as well as in the moraine now being made, and in the ice itself, appears to prove a recent retreat of the glacier, for these shells are of species now living in the waters of the fjord. They are found at a distance of five miles from the sea and at an elevation of 586 feet above it, and at various levels below this. The description of records left near the margin of this glacier is given, with the idea of putting forward facts which will permit accurate measurement of the change of ice front in the future. This seems all the more desirable, since evidence is abundant that the glacier in this part of Greenland is now retreating at a notable rate, and that it has recently withdrawn from a considerable area. The evidence of this is found in the presence of moraines at a distance of 100 or 200 feet from the present margin of the glacier, and so recently abandoned that no vegetation has begun to grow upon the soil. Moreover, freshly scratched bedrock has been so recently uncovered by the glacier that lichens have not begun to grow.

Unconformities in Marthas Vineyard and Block Island. By J. B. WOODWORTH.

Beginning below, plant-bearing beds of Cretaceous age appear in both islands, without their base being exposed. On Marthas Vineyard marine Cretaceous strata overlie the non-marine beds; although the contact has not been worked out, unconformity is inferred from the occurrence of lignitic fragments in the overlying marine beds. Above the Cretaceous at Gay Head, and on an eroded surface rests the Miocene of Lyell and Dall, composed of the osseous conglomerate and the greensand. Overlying these beds is a yellowish greensand, possibly Miocene but probably Pliocene. Fragments of a Pliocene formation have been identified at Gay Head by Dall. There was erosion in the area during or just after Eocene time, again between the greensand and the osseous conglomerate, and between the time of the greensand and the latest Neocene, the yellowish greensand. A bowlder formation now appears, composed of rocks derived from the mainland on the north. It was preceded by local folding of the underlying beds and by erosion along narrow channels, the Miocene being locally swept away. On Block Island the earliest Pleistocene rests upon the Cretaceous at Clay Head, the Miocene being entirely wanting. Succeeding the bowlder deposits there are from twenty-five

to thirty feet of granitic gravels and sands, the deposition of which was brought to a close by profound folding over Marthas Vineyard and Block Island. The Tisbury beds on Marthas Vineyard and the Mohegan Bluff beds on Block Island were now laid down upon the eroded surface of the upturned beds of older strata. These horizontal beds are evidently of glacial origin. After their deposition there came a long period of fluvial erosion, the Vineyard subepoch, in which the islands were deeply denuded, as pointed out by Shaler in 1888. On Marthas Vineyard the capture and beheadal of streams is shown in the existing topography as the work of this time. Then followed the last glacial epoch with the deposition of moraines and sand-plains.

The older Pleistocene deposits denominated Weyquosque by Shaler in 1888 appear to be the equivalent of the Columbia which in the region of the New England Islands is divisible into an upper and lower horizon, separated by unconformity of dip and erosion marking the Gay Head diastrophe. The author is unable to accept the hypothesis of glacial thrust for the deformation on the islands named because in each case the fold preceded the evidence of glaciation found in overlying bowlder deposits. Those who accept the ice-thrust hypothesis, it is insisted, must consider the work to have been done by two advances of an ice-sheet long anterior to the last glacial epoch.

In the discussion Professor Wm. B. Clark called attention to the evidence of unconformity found by him in New Jersey between the non-marine or Potomac beds and the marine Cretaceous, and also to the meagerness of the horizons in this northern extension of the coast-plain as compared with more southern fields. He suggested that an examination of the foraminiferal greensand might show that, as in New Jersey, the Miocene foraminiferal casts had at least in part been derived from preëxisting Cretaceous beds. Mr. Gilbert noted that the long erosion interval on the islands, preceding the last glacial epoch, was consistent with the history made out for the rest of the United States.

Homology of Joints and Artificial Fractures. By J. B. WOODWORTH.

A synopsis of the structure of a typical joint as described in a previous paper (*Proc. Boston Soc. Nat. Hist.*, Vol. XXVII, 1896, pp. 163–183) showed a central area of fracture termed the joint-plane, which is traversed by feather-fracture. Marginal to this is a border of overlapping fractures, traversed by cross-fractures, forming the "joint-

fringe." This system of fractures *en echelon* pervades the entire joint. Specimens were exhibited showing the joint structure above described, and also examples of fracture produced by blasting in a quarry, in which specimens there was a central warped surface corresponding to the joint-plane, and a system of marginal fractures comparable to the joint-fringe. The oblique imbricating plates formed by this fracture suggest a comparison with the "diagonal fissility" of Van Hise. The obliquity in the case of joints is found of value in determining the axis of breaking tension, whatever the nature of the force which produced the joint or fracture. This axis is a normal to the oblique marginal fractures. In mapping joints, a short straight line like the "strike" line crossed by short oblique lines having the obliquity of the observed marginal fractures of the fringe was proposed as a symbol. (Not to be published in the Bulletin of the Geological Society.)

Notes on Rock Weathering. By GEORGE P. MERRILL.

This paper was in direct line with those read at previous meetings of the Society, and had to do with the ultimate products of decomposition as shown in the transition of a fresh micaceous gneiss to the condition of a bright red residual soil. The results of physical and chemical analyses were presented, and on the assumption that the alumina had remained essentially constant during the decomposition, it was shown that 44.67 per cent. of original matter had been lost through the solvent and leaching action of water. The writer stated that on the basis that such results were rather under than above the actual amounts he had from a large number of analyses been led to the conclusion that an ordinary crystalline siliceous rock of a granitic or gneissoid type in passing by decay from its fresh condition to that of soil might lose about 50 per cent. of its original constituents.

The cause of the red color of the residuary material was discussed. The writer agreed with Professor Crosby in that the color was wholly superficial, but thought that such color might be due not wholly to dehydration of the ferric oxides present, but also to the presence of a large amount of coloring matter, the iron oxides having been shown to be largely insoluble, and hence accumulating in the residue along with the alumina. The subject of zeolites in soils, and their efficacy as conservators of potash was discussed, the conclusions being that not only is there no proof of the formation of zeolites, during the ordinary processes of true weathering, but also that even did zeolites exist in the

soils, such could hardly be of interest for the reason stated, since potash is not, on the whole, a prominent constituent of zeolitic minerals. In this connection Mr. Merrill suggested that the term weathering as applied to rocks should be limited to those processes going on within the zone of oxidation and resulting as a rule in the destruction of the rock was as a geological body, while the more deep-seated processes which result in the production of new minerals of the nature of zeolites, chlorite, epidote, etc., and which are really of mineralogical rather than geological moment, should be looked upon as metamorphic and designated as products of hydrometamorphism. In discussing the probable condition of the soluble constituents of soil, a brief table was given showing that in rocks of as diverse types as granite, phonolite, diabase and basalt, the percentage amount of soluble constituents in both fresh and decomposed materials may be very nearly equal.

Notes on the Potsdam and Lower Magnesian Formations of Wisconsin and Minnesota. By JOSEPH F. JAMES.

The observations recorded in this paper were made on a trip through Wisconsin and Minnesota during 1889. Starting from Madison, Wis., the route was through Lodi, Devil's Lake, Baraboo, Ableman's, Ripon, Winneconne, New London, Morritan, Hudson and River Falls, Wis., to Stillwater, Winona, and Dresbach, Minn. Natural and artificial exposures, especially in quarries, were studied at all of these places and others, and nearly all of them are illustrated by sections drawn to a scale. The most extensive section is that made between Knapp and Wilson stations on the line of the Chicago, Milwaukee, St. Paul and Omaha R. R. The distance between these two places is about five miles. There is a continuous up grade with many cuts and a number of exposures. The section extends from well down in the Potsdam up to and into the Lower Magnesian, with an estimated vertical range of about 140 feet. Two slabs of worm trails from the Potsdam of Dresbach and the Lower Magnesian of Prairie du Chien are also illustrated.

Preliminary Note on the Pleistocene History of Puget Sound. By BAILEY WILLIS.

During the past season the drift deposits about the southeastern edge of Puget Sound have been studied in some detail. They are found to consist of several beds of till, separated by stratified deposits

of clay, sand and coarse gravel, together with widely distributed lignite beds. The character and extent of the glaciation of the Puget Sound region are indicated in these deposits, and it is found that the principal flow of ice was rather from the north than from the mountains on the southeast. Two problems are presented by the phenomena: (1) The sequence of glacial advance and retreat and the extent and duration of climatic changes indicated by the presence of lignites; (2) the bearing of the peculiar conditions of glacial development upon the physiography of the sound. Either the deeper valleys of the sound have been eroded during a period of high level from the once more extensive sheets of drift or, as suggested by Russell, the channels represent the beds repeatedly occupied by glaciers which in their advance and retreat built up the plateau-like eminences of the region, probably upon the divides of the preëxisting topography. The past condition of Puget Sound under confluent glaciation is probably now represented by the Malaspina glacier and its attendant phenomena.

The Leucite Hills, Wyoming. By J. F. KEMP.

The paper opened with a brief statement of our earlier knowledge of the distribution of leucite, and of the special interest that attaches to it. Outside of the European mainland localities were cited on the Lipari Islands, the Cape Verde Islands in Asia Minor, Siberia, Java, New South Wales, Kilima-Njaro, Argentina, Brazil, New Jersey, Arkansas, Lower California, Yellowstone Park, Montana, and British Columbia. The presence of the rich alkaline magmas from Montana to the Mexican line, and in or near the eastern Rocky Mountains, was commented on. The previous observations of Zirkel on the rock of the Leucite Hills were briefly summarized so as to show that the only minerals observed by him in the very limited materials gathered by the geologists of the fortieth parallel were leucite in great abundance, small prisms of augite, biotite, apatite, and magnetite, and that the remarkable absence of feldspar, haüyne, and nepheline, was a cause of surprise to him. The geographical situation of the Leucite Hills and their areal distribution was then shown by lantern slides. There are three mesas or buttes in the main group, of which the southern, or Leucite Hills proper, is the largest. Orenda Butte, two or three miles north, is next, and Black Rock Butte, five miles northeast, is the smallest of all. The two former consist of several lava sheets resting on Laramie sandstones. From them arise cones 300 feet and less in

height that resemble craters, but that are solid lava. Black Rock Butte has no cone. The lava sheet is more or less dissected, but the fragments are found but a very short distance from the escarpment. Specimens from all the buttes, and from various parts of the southern one, show that while the leucite is almost always present it varies greatly in amount and may be replaced almost entirely by sanidine. Haüyne was observed, and in Black Rock Butte large augites with surrounding borders of the peculiar yellow biotite. All these points of petrographical interest were illustrated by lantern slides from photo-micrographs. The two published analyses were cited, and in view of the abundant sanidine the rock was called a leucite-phonolite rather than a leucitite. The cones were explained as due to the upwelling of a viscous lava in the final phases of activity. No tuffs or dikes were met. Pilot Knob, an isolated butte lying twenty miles further west and north of Rock Springs, was also described, and the rock was shown to consist of small needles and larger crystals of augite in an isotropic groundmass that was regarded as glass. The determinations of the rock as trachyte in the Fortieth Parallel Survey must have been due to a confusion of slides.

The Pre-Cambrian Topography of the Eastern Adirondacks. By J. F. KEMP.

The paper opened with a review of the geological formations in the Lake Champlain Valley. It was shown that Palæozoic sediments formed all the eastern shore except for a small area at the south. In Vermont the Georgian strata of the Cambrian are met, but Acadian representatives are lacking. The Georgian is only seen at a distance from the crystalline nucleus of the Adirondack Archæan (Algonkian) Island, whereas the Potsdam and Ordovician lie now well up on its flanks. Prolonged search has failed to show on the west shore of Lake Champlain anything below the Potsdam. Mr. Walcott has already pointed out these relations. The writer stated that the crystallines had all been formed and greatly metamorphosed long before the Cambrian times, whose strata on their flanks lie flat and show no metamorphism whatever. He further stated that the crystallines must have been land with an encroaching shore line during the Cambrian, and that the land was deeply carved by erosion, whose results he freely admitted had been greatly modified by faulting. Then, with a series of lantern slides based on the topographic maps of the United States

Geological Survey, he traced the relations of the Palæozoic rocks to the pre-Cambrian strata, showing that they set up into embayments at Willsboro, Essex, Westport and Port Henry. The most interesting of all are, however, at Crown Point and Ticonderoga. Small outlines of Potsdam were shown in the valley of Trout Brook, west of Rogers Rock on Lake George, and over a high divide; from the lake and in the valley of Lake George itself. The old depressions up which the encroaching sea of the late Cambrian set are still discernible. Then, with a succession of adjacent maps, the speaker traced out an old depression back from Lake Champlain through Crown Point, with several scattered outliers of Potsdam, thence southward past Penfield Pond, and up a branch in central Ticonderoga, where another Potsdam outlier is found; thence through the valley of Paragon and Paradox lakes into the Schroon Lake valley, where a few acres of Calciferous flinty limestone remain under Schroon Lake P. O. The last named exposure is nearly twenty miles from Lake Champlain, and is forty miles from the next outcrop down the Schroon and Hudson rivers. Attention was called to the little outlier containing Potsdam, Calciferous, Trenton, and Utica strata at Wells, on the Sacondaga River as recently figured by Mr. Darton. All these outliers are quite flat, seldom reaching fifteen degrees, and as a rule dip northwest and strike northeast. The original depressions were developed especially where there is crystalline limestone.

Stratigraphy and Palæontology of the Laramie and Related Formations in Wyoming. By T. W. STANTON and F. H. KNOWLTON.

The separation, in recent years, of the Denver, Arapahoe, and similar formations in Colorado, and of the Livingston in Montana, from the coal-bearing Laramie series, has called in question the unity of the beds usually referred to the Laramie in Southern Wyoming. Several facts in the reported stratigraphy and palæontology of the region suggested the possible presence of the Denver beds. The same horizon was suggested by the vertebrate fauna of the "Ceratops beds" in Eastern Wyoming as described by Messrs. Marsh and Hatcher. In view of these facts and queries the authors undertook the examination of the Ceratops area in Converse county, and of the coal-bearing localities along the Union Pacific Railroad, giving special attention to the stratigraphy and to the branches of palæontology—invertebrates and plants—in which they are respectively interested. The areas studied in

Converse county, the Laramie Plains, and Bitter Creek valley are described somewhat in detail, and more general observations are given on other localities treated, including Evanston and Hodge's Pass, Wyoming; Coalville, Utah, and Crow Creek, Colorado. The results are negative so far as the Denver and later related formations are concerned. That is, no division of the beds between the base of the Laramie and the Fort Union was found possible, and the Laramie age of the Ceratops beds of Converse county, as well as of the Black Buttes coal horizon, was confirmed. On the Laramie Plains most of the coal-bearing localities are on a horizon lower than the Laramie, and overlain by marine Fox Hills beds. The coal-bearing series at Point of Rocks is also in a similar position, and the considerable flora it has yielded must now be referred to the Montana formation instead of to the Laramie. In this connection all the non-marine invertebrates and plants now known from the Montana formation are brought together in lists, and the more general questions of the upper and lower delimitation of the Laramie are discussed.

A Complete Oil-Well Record in the McDonald Field between the Pittsburg Coal and the Fifth Oil Sand. By I. C. WHITE.

Geologists have long desired a careful and accurate measurement of the rocks passed through by the borings for oil in southwestern Pennsylvania. Mr. Carll, during the life of the second geological survey of Pennsylvania, had several careful records kept of the borings in Clarion and adjoining counties, but as the strata dip to the southwest, and thicken somewhat, it was very desirable to have a new standard of comparison in southern Pennsylvania. The writer happily found in Mr. T. J. Vandergrift of Jamestown, N. Y., a successful oil operator of many years' experience, the right man to undertake the work purely as a labor of love in the interest of geology. The well in question was drilled by the Woodland Oil Company, of which Mr. Vandergrift is president, on the S. B. Phillips farm in the famous McDonald field, near the line between Allegheny and Washington counties, Pa., about twenty miles southwest from Pittsburg. The producing rock of this region is the lowest member of the Venango Oil Sand group, or what is known to oil operators as the Fifth Oil Sand. This rock, it will be remembered, has yielded petroleum in greater quantity than any other yet found on the American continent, since some of the wells of the McDonald region produced oil for a short

time at the rate of 15,000 barrels daily. It is no slight task to keep one of these deep-well records with the necessary care, since to be reliable a sample of the drillings must be washed, dried, and properly labeled every time the tools are withdrawn from the well. Then, too, as all rope measurements are not reliable to within ten to fifteen feet, steel-line measurements must be taken frequently, all of which was done in the present instance, so that the 2342 feet of strata, penetrated from eighty-six feet above the Pittsburg coal down to seven feet under the base of the Fifth Oil Sand, is represented by 570 samples of drillings and fifty-five steel-line measurements, from which data a very complete account of the rocks from the Pittsburg coal down nearly to the top of the Chemung may be obtained, for all of which geologists are certainly under great obligations to Mr. Vandergrift. The writer will publish the log of the well, as noted by the party keeping the same, and also a condensed record in more strictly geological terms.

A Note on the "Plasticity" of Glacial Ice. By ISRAEL C. RUSSELL.

Experiments by McConnell, Kidd, and Mügge have demonstrated that a bar of ice cut from a single crystal, with the optic axis perpendicular to two of the side faces, when subjected to a bending stress, will bend freely in the plane of the optic axis, but not at all in a plane perpendicular to that axis. In the bent crystals the optic axis in any part is normal to the bent face in that part. As stated by McConnell, the crystals behave as if they were composed of an infinite number of thin sheets of paper, normal to their optic axis, and attached to each other by some viscous substance which allowed one to slide over the next with great difficulty. The greatest freedom of movement was found to occur when the ice experimented on was near the melting point, and became less and less with a decrease of temperature. In certain of the experiments referred to the freedom of movement at -2° C. was twice as great as at -10° C. When thin sections of glacial ice are examined by means of polarized light, as shown by Deeley, Fletcher, and others, it is seen that the granules of which it is composed are fragments of ice crystals, or perhaps imperfectly formed crystals which interlock one with another so as to resemble the structure of coarsely crystalline dolomite.

The optic axes of the granules are without definite arrangement, but have all directions. Pressure brought to bear on such granular ice in a definite direction would cause movement in the crystal frag-

ments or granules, whose optic axes were in the plane of pressure, but would not change the forms of the crystal fragments not thus oriented. The crystal fragments having their optic axes in the plane of pressure would be changed in shape, as in the experiments cited above, by movements along gliding planes. The stresses in glaciers are manifestly in various directions, and owing to the flow of the ice, inequalities of the rock surfaces beneath, etc., must be exceedingly complex. As the crystal fragments of which glaciers are composed are without orderly arrangement it is evident that some of them will be properly oriented to be deformed by a differential movement of their parts along gliding planes, by pressure acting in any direction. Under diverse stresses the resultant motion would be in the direction of least resistance. That is, the granular ice would behave like a plastic solid. The yielding of glacial ice to pressure, we conceive, is due to movements along gliding planes in the granules of which it is composed. If this process is continued the granules will evidently be destroyed by being divided along the planes on which movement occurs, but the resulting subdivisions, or "plates" perhaps we may term them, are reunited probably by the process of regelation. The plates, which after uniting have the same orientation, would form new granules. The longer this process is continued, or, in other words, the farther a glacier flows the greater the chances that a large number of "plates" will come together with similar orientation and the larger will be the resulting granules.

Under the hypothesis here suggested the granules of glacial ice are considered as an inheritance from the granules in the ice formed by partial melting and refreezing of névé snow. The granules at first are minute, but under the pressure of ice at higher levels they yield along gliding planes, and a resultant motion similar to that of plastic solids under like conditions is initiated. The granules are destroyed by this process, but progressive motion leads to the union of a constantly increasing number of the plates into which they are divided, and the growth of larger granules.

Work of the U. S. Geological Survey in the Sierra Nevada. By H. W. TURNER.

To the north of the Fortieth Parallel Mr. Diller has published one folio on the Lassen Peak area, and has a very extensive series of notes which are as yet unpublished. The gold deposits of the Sierra

Nevada are, with minor exceptions, pretty closely confined to the belt of Palæozoic and Juratrias slates with their associated greenstones and included granitic masses. The area covered by these rocks forms the real gold belt of the Sierra Nevada. It is gratifying to announce that the geological work covering this area is now nearly completed. The Marysville, Smartsville, Sacramento, Placerville, and Jackson folios are published, and the Bidwell Bar, Downieville, Truckee, Pyramid Peak, Big Trees, and Sonora sheets are soon to be published. Attention was called to the very extensive beds of Juratrias tuffs in the foothills, indicating enormous volcanic activity in Juratrias time. Later in the Tertiary the scene of volcanic activity was transferred to the crest of the range, and nearly the whole area of the gold belt was flooded with lavas chiefly of a rhyolitic and andesitic character.

Shore Lines of Lake Warren and of a Lower Water Level in Western-Central New York. By H. L. FAIRCHILD.

This paper describes the eastward extension of the Warren shore line as discovered and traced by the author during the past summer. The beach, in excellent form, with the various shore-line phenomena, as cliffs, bars, spits, and hooks, has been traced from Crittenden to Lima, somewhat east of the meridian of Rochester; while sufficient evidence of static water at a corresponding level is found much further eastward. The altitude of the beach between Batavia and LeRoy is 880 feet above tide. The altitude at Lima, subject to possible correction of datum, is 877 feet. This water plane would lie just about 500 feet over the Iroquois plane and would apparently lie below the plane of Watkins Lake or of Lake Newberry, the early local glacial waters in the Seneca embayment. It therefore seems certain that the Warren waters never found outlet by the Horseheads channel. The comparison of the beach phenomena east of Indian Falls with the same phenomena at Crittenden and westward is difficult to make on account of the difference in the topography of the country. East of Indian Falls the beach is transverse to the drumloid molding of the land surface, and the beach is not of so mature a character as south of Lake Erie, but nevertheless indicates a long period of wave action. Another beach at an altitude of 700 feet has been found at Geneva, New York, and traced westward continuously nearly to the meridian of Canandaigua. Abundant evidence of the same water plane is found in terraces and cliffs nearly to the Genesee River. The phenomena of this shore line

are nearly as strong as those of the Warren waters in the Genesee region. This beach is specially interesting as being entirely new and unexpected, and indicating a long pause of the waters at an altitude between the Warren and the Iroquois plane, while the correlating outlet is unknown. The body of the paper is a detailed description, for record, of the phenomena of these two beaches.

Principal Features of the Geology of Southeastern Washington. By ISRAEL C. RUSSELL.

A brief statement of the results of a six weeks' reconnoissance in the southeastern portion of the state of Washington, made for the United States Geological Survey.

Practically all of that portion of Washington which lies south of the Big Bend of the Columbia is occupied by a succession of basaltic lava flows. This is a portion of a vast lava-covered region embracing northern California, central and eastern Oregon, central and southeastern Washington, and southern Idaho. The great fissure eruptions which supplied the Columbia lava, as the basalt is termed, occurred in the Miocene. The Columbia lava in Washington to the west of the Columbia, south of the Big Bend, as ascertained during a previous reconnoissance, is broken by extensive faults and the blocks thus formed variously tilted. In the region here treated, however, the basalt is horizontal over extensive areas, and deeply dissected by Snake River and its tributaries. Many lava sheets, one resting on another, were seen. Between some of the flows there are widely extended sheets of lacustral clay, sand, gravel, volcanic dust, and lapilli. In some instances leaves, and the silicified stumps and trunks of trees occur in these layers. The Columbia lava flowed about the bases of the mountains of eastern Washington and the adjacent portion of Idaho, in a series of inundations which covered the low country to the south. The level basaltic plateau meets the mountains of metamorphic rock in much the same manner that the sea joins a rugged and deeply indented coast. The lava entered the valleys and gave them level floors of basalt; the deeply sculptured ridges between the valleys were transformed into capes and headlands; outstanding mountain peaks became islands in the sea of molten rock. After the last of the lava sheets was spread out, the rivers flowing from the mountains began the excavation of channels across the basaltic plateau and have deeply dissected it. The most important of these channels is the one

excavated by Snake River. From the mouth of Snake River to Lewiston, the stream is a narrow, deep-sided canyon, about 2000 feet deep. Where Snake River forms the boundary between Washington and Idaho, its gorge is about 4000 feet deep and fifteen miles broad. Within this vast canyon there are many lateral ridges, and a great variety of topographic forms due to erosion. This portion of Snake River canyon compares favorably with even the most magnificent parts of the Grand Canyon of the Colorado, except that it lacks the gorgeous coloring to which so much of the charm of its southern rival is due. The thickness of horizontally bedded basalt exposed in the walls of Snake River canyon and in the adjacent Blue Mountains, is in the neighborhood of 5000 feet, but the maximum thickness is not exposed. In the walls of the canyon at three localities, the summits of steep, angular mountain ranges are revealed. One of these buried peaks rises about 2500 feet above the river and is covered by fully 1500 feet of horizontally bedded basalt. The sheets of clay, sand, and gravel interleaved with the basalt, especially near its junction with the bordering mountains, furnish conditions favorable for obtaining artesian water. A number of flowing wells derive their water supply from this source. The Blue Mountains, at least at their northern extremity, consist of a low, flat-topped dome of Columbia lava, which has been deeply dissected by consequent streams. The surface of the basaltic plateau is covered with residual soil which has an average depth of sixty to eighty feet over thousands of square miles. The soil is exceedingly fine, dark brown or black in color, and of wonderful fertility. This is the soil of the celebrated wheat lands. The subsoil is fine, light yellowish in color, without stratification, and in many localities traversed by minute, irregular, but, in general, vertical tubes. In many ways the subsoil closely resembles loess. Its origin from the disintegration and decay of the underlying basalt is clearly manifest.

Topographically the Columbia lava presents great diversity. In the Blue Mountains there is an intricate series of sharp-crested ridges, separated by a labyrinth of canyons, having in general a depth of about 3000 feet. Between the Blue Mountains and Snake River there are broad remnants of the nearly level plateau, separated by narrow, steep-sided canyons, in general 2000 feet deep. North of Snake River there is a vast area without deep canyons, but diversified by short hills from fifty to eighty feet high, none of which, however, rises above a certain general level. Along the eastern portion of this hilly plateau, or rolling prairie as it was before cultivation began, there are a few

prominent, island-like buttes of quartzite, which rise through the basalt. Among the details noted in the Columbia lava are certain horizontal joints which cut the vertical columns of basalt and may be traced for several miles. The large vertical columns of lava when weathered sometimes show that they are composed of small horizontal columns or prisms which radiate from a confusedly jointed central core. The joints which bound the large vertical columns furnished the cooling surfaces for the rock they enclose. The bases or ends of the radiating columns are frequently revealed on the surfaces of the slightly weathered vertical columns by a network of lines resembling shrinkage cracks. A report on the observations outlined above will be published by the United States Geological Survey.

Old Tracks of Erian Drainage in Western New York. By G. K. GILBERT.

The glacial Lake Warren occupied the Erie and parts of the Huron and Ontario basins. In the next important stage Lake Erie was established as a non-glacial lake, being separated from the glacial Lake Algonquin at the west and the glacial Lake Iroquois in the Ontario basin. As Warren drained westward and all the lakes of the succeeding stages drained eastward, it was inferred as probable that the revolution was initiated by the opening of an eastward passage for Warren waters. Such eastward passage was sought and found in western New York. In fact several passages were found, which succeeded one another as the northward retreat of the ice-front exposed lower and lower cols on the north-south ridges which diversify the general northward slope of that region. Between the ridges there were lakelets, walled by ice on the north, and these lakelets received the material scoured out by the waters in crossing the ridges, so that the surviving phenomena are chiefly channels and scourways through the higher lands, with gravel deltas at their eastern ends. Most of the drainage lines descend to the Iroquois level, but some terminate at higher levels, and it is thought probable that for a short time a glacial lake occupied the middle Mohawk valley, being doubly dammed by ice lobes on the east and northwest.

The district traversed by the channels extends from Le Roy to Chittenango, and the relation of the channels to one another and to the Iroquois shore show that during the channel epoch the trend of the ice-front in that region was approximately east-west.

It was found also that when the water first fell to the level of the Niagara escarpment, so as to cascade over its edge, there were five points of discharge. Three of these were short-lived, but Lockport for a considerable period divided the water with Niagara.

The Physical Nature of the Problem of General Geological Correlation. By CHARLES R. KEYES.

The main object of this communication has been to formulate briefly certain suggestions which have arisen in the course of recent attempts to parallel some of the geological formations in the Mississippi valley. They appear to have a much more than local bearing, and to affect the whole problem of general geological correlation, and perhaps also even our present system of geological classification.

Regarding as the principal function of correlation the establishment of a practical scale of geological succession to which may be referred the strata of all parts of the globe, the critical criteria adopted became essentially the real basis of geological classification or historical geology. A rational classification of geological phenomena reflects the genesis of the events recorded, and this is manifestly the ultimate aim of all methods of paralleling strata. In the correlation, or comparison of geological formations, experience has shown that the subject may be viewed from at least four very different points of vantage. The aspects presented are: local, provincial, regional, or general. With the various methods which have been followed from time to time in correlative inquiry the almost universal practice has been to attempt to base the broader generalizations upon criteria that are in reality applicable only to limited areas.

Passing by a review of the various methods of correlation which have been used, a little consideration shows that all are necessarily local in application and not general. This distinction between the two sorts of correlation which is usually entirely overlooked should be clearly borne in mind. When widely applied the almost total failure of the several methods that have been tried is only too apparent. The inherent weakness of the most common criteria — the fossils — is readily gleaned from the writings of Huxley, Irving, Van Hise, McGee, Walcott, Brooks and others. The problem is manifestly a physical and not a biological one. We must look therefore to physical criteria for its solution. The nearest approach to an absolute foundation for a system of geological synchrony is to be found in the work of Irving,

in his work on the pre-Cambrian crystallines of the northwest, in which unconformities are given great prominence; by McGee in his investigations of the coastal plain deposits of the Middle Atlantic slope, in which similarity of genesis, or homogeny, is the governing factor; and by Davis and others in physiographic work, in which periods of base-leveling are made the all-important features in the cycle of land degradation, and inferentially the consequent sedimentation in adjoining seas.

Without considering all the available physical and biotic criteria of correlation in these various local and general phases it may be said that general correlation finds a fertile suggestion for a rational foundation in the factors which govern sedimentation. Its chief criterion is a function of continental growth and decline, and is dependent upon orogenic movement. This has recently be encalled correlation by mountain-building cycles, or orotaxis. The division planes cutting the geological columns into systems, series, or smaller parts, are actually, as well as theoretically, the lines of unconformities and their representatives. In the case of the more extensive ones they do, no doubt, represent base-leveled surfaces, or peneplains.

Modified Drift in St. Paul, Minnesota. By WARREN UPHAM.

Within the limits of St. Paul (fifty-five square miles) are numerous plateaus of drift gravel and sand, 225 to 240 feet above the Mississippi River, and about 100 feet above the highest plains and terraces of similar modified drift in the Mississippi valley. The courses of marginal moraines in this city and its vicinity, the glacial striæ, and diverse origin of the glacial and modified drift on the east and west, show that the slopes and currents of the ice-sheet converged to this area from the northeast and the northwest. On account of the sigmoid course of the Mississippi valley here, during the final melting and retreat of the ice-fields the tract where they had been confluent was occupied by a small glacial lake named Lake Hamline, which extended over the greater part of the western half of the area of St. Paul, having an outlet toward the southwest and south, across the present watershed between the Minnesota and Mississippi rivers, to Rich Valley and the Mississippi. In this temporary lake the modified drift plateaus were accumulated, their material being thought to be supplied from exceptionally abundant englacial drift brought to the area of glacial confluence. The surface of the glacial lake during the

early part of its existence, as shown by the Hamline and Como plateaus, was about 250 feet above the present river, or 930 to 940 feet above the present sea level. A little later, when the plateau a mile east of Lake Como was formed, the lake level had fallen apparently five or ten feet. At the time of formation of the Summit Avenue plateau, it had been further lowered several feet, having then apparently an elevation of about 915 feet; and still later and smaller plateaus show that this lake finally was reduced to 875 or 870 feet above the present sea level. In one section it was observed that the till, exposed to a depth of twenty to twenty-five feet, at an elevation of about 875 to 900 feet above the sea, has throughout that thickness an imperfect stratification. The author attributes this to the action of the water of Lake Hamline, receiving the till from a previously englacial and superglacial position in and upon the melting ice-sheet. It is an observation almost exactly like that made by him a year earlier in the drift section of the Lake Erie shore in Cleveland, Ohio; and here, as there, he concludes that the volume of the englacial drift is represented by the thickness of the obscurely bedded or laminated till. In another section a sheet of till ten to twelve feet thick, resting on striated Trenton limestone, is shown, as the author thinks, to have been wholly englacial, this being indicated by deflection of the glacial striæ. Many of the striæ, intersecting the southward courses of earlier glaciation, run N. 60°–75° W., perpendicularly toward the neighboring Lake Hamline and its long plateaus of water-deposited drift.

(Abstracts to be continued.)